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The Astrolabe and Medieval English Life

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"And men may well preven be experience and sotyle compassment of Wytt, that zif a man fond passages be Schippes, that wolde go to serchen the World, men myghte go be Schippe alle aboute the World, and aboven and benethen. The shiche thing I prove thus, aftre that I have seyn. For I have ben toward the parties of Braban, and beholden the Astrolabre, that the Sterre that is clept the Transmontayne, is 53 Degrees highe. And more forthere in Almayne and Bewne, it hathe 58 Degrees. And more forthe toward the parties septemtrioneles, it is 62 Degrees of heghte, and certeyn Mynutes. For I my self have mesured it by the Astrolabre."

(*The Voiage and Travaile of Sir John Maundeville, Kt.* J. O. Halliwell, ed. London: Reeves and Turner (1883).)

SOME ASPECTS OF THE ASTROLABE: ITS HISTORY AND ITS USE IN ENGLAND

I

In the light of modern investigation, Sir John Mandeville has dropped from his former glory. There seems to be a basis in fact for parts of the tales told, but much of it seems to be imagination and second-hand report. One editor, Arthur Layard, believes the tales to be the work of someone trained in a monastery, who may at one time have served as a sort of squire to a knight. One point seems positive; "Other liars have been callous and brazen: Sir John is always modest and conscientious."[1] Like Pooh Bah, he knew the value of "corroborative detail, intended to give artistic verisimilitude to an otherwise bald and unconvincing narrative." If the author of the tales made the observations he writes about, he is to be respected for his earnest endeavor to accurately describe and record things he saw. If the author was perpetrating a gentle hoax, his method is to be admired. But to the student of the history of science it is especially interesting, for it shows the astrolabe to be so well known in the fourteenth century that a writer

[1] *Voyages and Travels.* Sir John Mandeville. (Arthur Layard, ed.) New York: Appleton (1901). p. x.

could use it to swell the flood of detail in a narrative which helps swing the reader over the spots that may be a shade on the side of the improbable. The astrolabe had come into its own by the XIV century and still had a long, vigorous, and important career ahead.

The purpose of this paper is to give a short survey of the astrolabe in medieval England. The instrument will be described and its astronomical context examined. The uses of the instrument will be touched, as will certain aspects of Chaucer's treatise on the astrolabe. In short, it is an attempt to place the astrolabe in a light that will clarify its place in medieval English life and science.

The term "astrolabe" has been variously used by commentators throughout the history of astronomy. It may be construed to include armillary-type instruments, but throughout this paper, the term will refer only to the "planispheric astrolabe," since that is the customary use of the term by the leading authors today. (The term "planispheric" will be discussed in its proper place in the body of the paper.) Typical of the nonplanispheric type instrument is one pictured by Zinner[2] as a sketch of Ptolemy's astrolabe. This sketch, which shows an instrument that resembles an armillary, throws light on other authors' description of Ptolemy's instrument. (See Note 7.)

Hipparchus gave to western astronomy its first great impetus. He studied and observed at Rhodes from c. 161 to 126 B.C. Some authors attribute to him the invention of trigonometry. He did invent the longitude-latitude system of "fixing" positions for reference, and he discovered the precession of the equinoxes.[3] He was a tireless observer, and catalogued a thousand or more stars. (A commentary on the *Phaenomena* of Aratus and Eudoxus is the only work by him which survives.) However, it was not until Ptolemy began his observations and study that the work of Hipparchus[4] was fully expounded and appreciated.

Ptolemy—Claudius Ptolemaeus[5]—lived and observed at Alexandria in the first half of the second century A.D. He was a versatile scholar and his works include writings on geography, astronomy, and related

[2] Ernst Zinner. *Geschichte der Sternkunde*. Berlin: Springer (1931). p. 90.

[3] "Precession of the equinoxes" refers to the fact that the year of the seasons is shorter than the year determined by the time at which certain constellations rise and set with the sun. It implies the idea of the equinoxes moving "forward" to meet the sun. This gives a difference of about 20 minutes of time per year. For a discussion of precession, see: H. N. Russell, R. S. Dugan, and J. Q. Stewart. *Astronomy*. New York: Ginn (1945). Vol. I, p. 141 ff.

[4] R. W. T. Gunther, in his *Astrolabes of the World* (Oxford: University Press (1932)), attributes the invention of the planispheric astrolabe to Hipparchus. Gunther writes, "It is said that he was the first man to apply a theory of stereographic projection to the drawing of the celestial sphere upon the plane of the equator. The planispheric astrolabe is impossible without this projection . . ." p. 53, v. I. Gunther indicates that Hipparchus was probably greatly indebted to the Chaldeans for much of his thought and work.

[5] Claudius Ptolemaeus was often confused with some one of the kings of the Ptolemaic dynasty of Egypt. For an interesting note on this confusion, see: G. A. Plimpton. *The Education of Chaucer*. New York: (Oxford (1935). pp. 94, 111.)

subjects. Ptolemy was very much indebted to Hipparchus, but his works far exceeded those of his predecessor. The *Almagest*[6] was the result of Ptolemy's many labors and was the authority to which medieval astronomers turned. One of his major contributions to science was the star catalogue included in the seventh and eighth books of the *Almagest*. This catalogue was a remarkable achievement, and one author says:

"It is the first and most ancient document we possess which gives a description of the heavens of sufficient exactness to admit of comparison with modern observations. For many centuries it was held in highest repute, and indeed, until the time of Tycho Brahe it was practically the only source of information of the positions of the stars which the world possessed; for though in the fifteenth century Ulugh Beg prepared a much more accurate catalogue of Ptolemy's stars, it never came into general use."[7]

Ptolemy is most widely known for the system which bears his name. In short, it was a geocentric system, and the orbits of the sun and planets were seen as a series of epicycles. This system of epicycles refers, fundamentally, to a system wherein each planet revolved about a fictional center. In turn, this "center" revolved about the earth in its circular orbit, or "deferent." Venus and Mercury were distinctive in that they revolved about the earth on their deferents once a year and were always between the earth and the sun.[8] In the course of continued study, epicycle was added upon epicycle by Arabian astronomers until the system became very complicated. The system denied the rotation of the earth upon its axis. However, since Ptolemy's hypothesis explained the motion of the planets and enabled the astronomer to predict, it was acceptable. The Ptolemaic system prevailed until Copernicus (1473-1543) published his theory which replaced the older ideas. However, the epicycle system survived, in one form or another, until Kepler (1571-1630) formulated his laws and showed that the planetary orbits are elliptical.

Thus, the importance of Ptolemy's work to the medieval astronomer is readily apparent. Ptolemy was the author of what was perhaps the greatest single scientific work which had appeared. The observations

[6] No single definitive edition of Ptolemy's *Almagest*—which embodies his geography and astronomy, among other subjects—has ever been published.

[7] C. H. F. Peters and E. B. Knobel. *Ptolemy's Catalogue of Stars, A Revision of the Almagest*. Washington: Gibson (1915). p. 7.

Here, the armillary sphere is said to have been the instrument employed by Ptolemy. It is probably the same type instrument referred to by Zinner. The armillary sphere which we know is quite different from the astrolabe. Briefly, the armillary sphere consisted of a series of metal rings which represented the "celestial spheres." A meridian and a horizon were similarly represented and imposed about the whole series. The rings were movable and could be made to rotate about a polar axis. The system was then, usually, mounted upon some sort of stand or base.

[8] See: *Astronomy*, p. 243 ff. The authors hint that the system—or a similar one—may have been developed by the ancient Egyptians.

which came down from Ptolemy remained unsurpassed until Tycho Brahe began his astronomical studies.* Although many astronomers gained wide repute between the time of Ptolemy and that of Chaucer, none seriously altered or affected astronomical thought. The writings on astronomy in Chaucer's day and later were usually translations — with or without some further elaboration—or re-workings (such were the later editions of Ptolemy's star catalogue) of the material of the *Almagest*.

II

A description of the make-up of the astrolabe is necessary to visualize its place in medieval English life and science. The material which follows is based on Gunther's translation,[9] Skeat's edition, and Robinson's edition.[10] Astrolabes of the fourteenth century varied from instrument to instrument, but the description which Chaucer wrote is applicable to the vast majority of existing instruments.

The body of the astrolabe was called the "mother." (Figure 1). The mother is a heavy disc of metal with a border—a wide ring of metal—affixed to one side. (This ring was riveted in place and the edge filled to make a smooth disc with a large, flat, uniform cavity on one side—the "front half.") The disc is then tooled at one edge to receive the thumb-ring post which holds the thumb-ring. The mother is allowed to hang free and plumb on its ring and the meridional line is made. (It vertically bisects the mother.) This line is crossed at the center of the cavity (at right angles) by the east-west line. The border is then divided into 24 equal parts, each part representing one of the 24 hours, each designated by a letter of the alphabet, in order and clockwise from south. (See Figure 2.) The quadrants are marked in the border, and are further divided into degrees, 0 to 90 in each quadrant. (In Chaucer's sketches, every fifth degree is marked, and every tenth degree is

*See: Arthur Berry's *A Short History of Astronomy*. New York: Scribner's (1899). pp. 68-73. Berry's discussion of Ptolemy's works, especially the star catalogue, would indicate something quite different from the position suggested by Peters and Knobel (note 7, above). An examination of the catalogue of Ptolemy, says Berry, reveals that it is probably not Ptolemy's own work. "It is therefore probable that the catalogue as a whole does not represent genuine observations made by Ptolemy, but is substantially the catalogue of Hipparchus corrected for precession and only occasionally modified by new observations by Ptolemy or others." (p. 69). Berry also notes that "Throughout the Middle Ages his authority was regarded as almost final on astronomical matters, except where it was outweighed by the even greater authority assigned to Aristotle." On Ptolemy's observations, we find the words, "That his [Ptolemy's] observations, if not actually fictitious, were at any rate in most cases poor." (p. 73.)

[9] R. T. Gunther. *Chaucer and Messahalla on the Astrolabe*. (*Early Science at Oxford*, Vol. V) Oxford: University Press (1930). Gunther's translation is the only existing one of Chaucer's treatise. It includes the original illustrations, a translation of Messahalla's *Compositio et Operatio Astralabie*, and photocopies of the pages of a manuscript of Messahalla's treatise.

[10] W. W. Skeat. *The Astrolabe*, by Geoffrey Chaucer. Early English Text Society, Extra Series, No. XVI. London: Trubner (1872). A detailed study, it has extensive notes, comments, and a series of sketches. F. N. Robinson, *The Poetical Works of Chaucer*, Boston: Houghton Mifflin (1933).

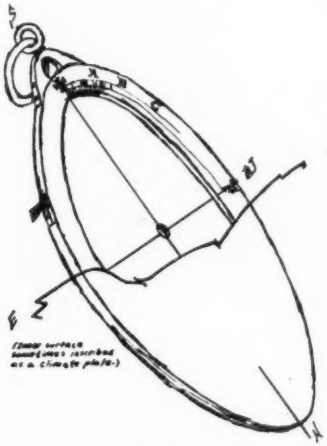

FIGURE 1

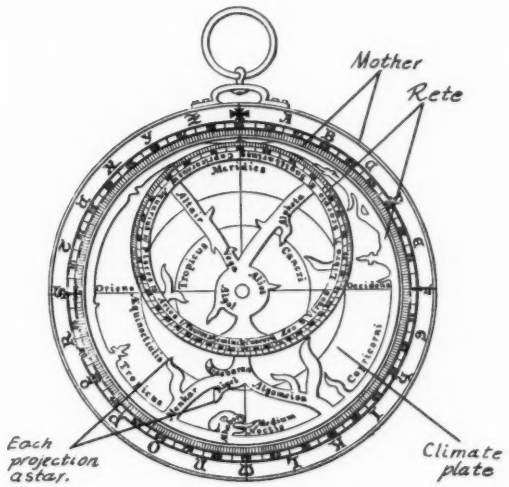

FIGURE 2*

Astrolabe; front half; zodiacal ring represents the zodiacal circle, 30° in width. Center line of zodiacal ring represents the ecliptic. (Copy after Skeat.)

numbered.) Each degree on the border represents four minutes of time. (Five degrees represent a "mile-way," or the average time it takes to walk a mile. Three mile-ways (15 degrees) equal one hour.)

*Figures 2, 3, and 4 are taken from *The Astrolabe*. Goeffrey Chaucer. Edited by Walter W. Skeat. London: Trubner (1872).

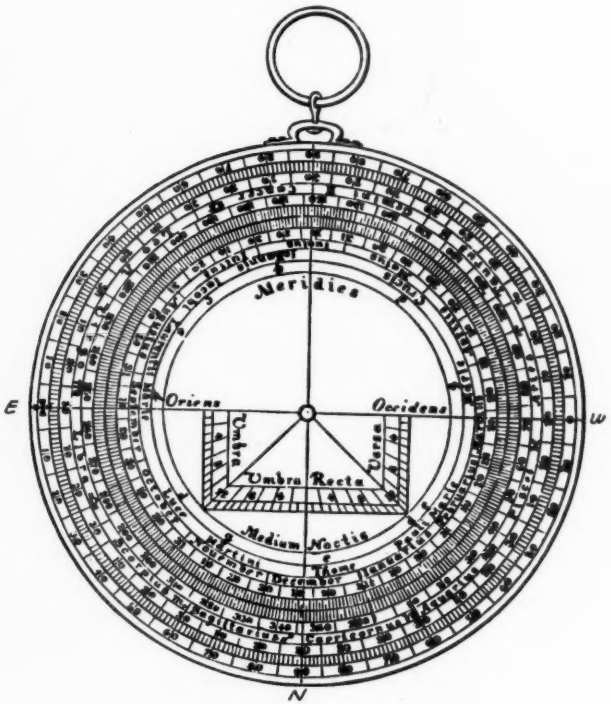

FIGURE 3
Reverse side of Figure 2

The reverse or "back half" of the mother is divided into quadrants coincident with the quadrant divisions on the front half. (See Figure 3.) The back half is scored off with a number of circles, each divided as follows, reading from the outer-most circle toward the center:

(1) Quadrants, divided into five-degree increments, numbered every tenth degree.

(2) Degrees of the circle.

(3) Circle, increments of five degrees, numbered every tenth degree from ten to thirty, for each sign of the zodiac.

(4) Circle of the signs of the zodiac.

(5) Days of the year in five-day increments, numbered every tenth day.

(6), (7) Days of the year and days of the months.

(8) Circle of months, in five-day increments, numbered every tenth day, last number in each month varying according to the number of days in the particular month.

(9) Circle of the months.
(10) Circle of the Saints' days.
(11) Sunday letters of the Saints' days.

In the lower half of the front half, within the circle of Sunday letters, the shadow scales (Umbra versa and umbra recta,/or "extensa"/) are drawn.[11] A small cross, reference point for many operations, is drawn on the east line.

The "climate" plates are circular metal discs which fit snugly into the cavity of the mother. The term climate here refers to the latitude for which a given plate is inscribed. (See Figure 4.) The plate is divided into four quadrants, and the intersection of the quadrant lines is the center of three circles, the "Circle of Cancer," the "Equinoctial Circle,"

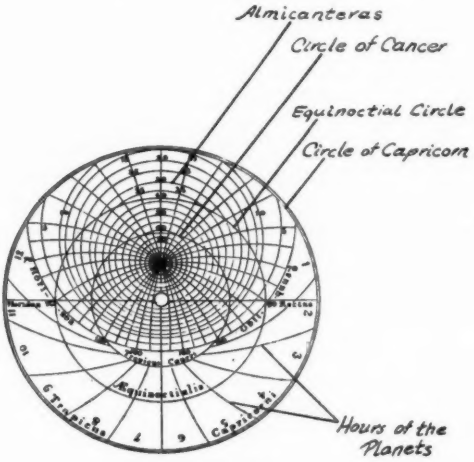

FIGURE 4

Generally, the larger and better the instrument, the greater the number of almicanteras. The center point of the almicanteras, represents the zenith—the point in the sky above the observer's head. Dalton, in describing the Byzantine astrolabe at Brescia, says, "The number of almucantars actually engraved varied widely. The Arabs called an instrument perfect (Tamm), when it was engraved with the full number of ninety almucantars. When every other parallel was engraved, it was a *Nisfi*. If it had thirty, *i.e.*, if no more than every third parallel was marked, it received the name of *Thalthi;* if there was only a line for each five degrees, it was a *Khumsi*, showing eighteen parallels; if one line for every six degrees, it was a *Sudsi* showing fifteen." (*Proceedings of the British Academy, 1926.* London: Oxford University Press.)

Skeat's sketch, copied here, would be a "Khumsi," with a parallel for every five degrees from the horizon ("horizon obliquus") to the zenith. The "Tamm" type instruments were not especially rare; Gunther describes one in *Early Science at Oxford*, II, p. 218.) and many examples in *Astr. of the World.*

[11] The shadow square was "the most important part of the astrolabe so far as surveying is concerned. To al-Battani (850-929) goes the credit of introducing the shadow square on the astrolabe." E. R. Kiely. *Surveying Instruments.* New York: Bureau of Publications, Teachers' College, Columbia University (1947).

and the "Circle of Capricorn." The almicanteras, the azimuths, and the hours of the planets are also inscribed.

The rete has the strangest appearance of any part of the astrolabe. (The parts of the rete are listed on Figure 2, and the accompanying note.) The rete is made in one piece and rotates around the common center pin of the instrument. Two straight-edges, one on each half of the instrument, were employed. The "rule" was the term applied to the straight-edge on the back. On the rule were the sights used in measuring angles by observation. The label was a simple straight-edge used on the front half.

III

Haskins would date the entry of the astrolabe into Western Europe at about the eleventh century.[12] In the course of the extension of Arabic learning, the instrument found its way into England. That the astrolabe was unknown in England before the eleventh century seems doubtful. In the centuries that elapsed between Augustine's arrival in Kent and the first writings (which survive) on the astrolabe, the instrument must have been known to at least a few of the more scientific scholars. The best arguments for the late arrival of the astrolabe in England lie in the fact that the oldest known astrolabe, the "Anticythera" astrolabe, dates back to c. 250 A.D.,[13] the earliest surviving Arabian instrument is dated c. 950, Moorish, 1029-30, and the earliest of the English instruments is the Sloane[14] which is variously dated c. 1280 to c. 1340. The gap between the Anticythera astrolabe and the first Arabian astrolabe would indicate that the instrument was not so widely known during that period. This does not mean that the instrument was unknown and undeveloped; manuscripts and records of manuscripts indicate some interest in the astrolabe in those early days. Astrolabes came west with the Arabs across north Africa c. 650. This same Arab stock produced the Moors who invaded Spain and ruled there for many centuries. From their position of strength in Spain, the Moors fostered the sciences during this period, and to them the credit for keeping interest alive must be given.

We may consider the year 1091 as the approximate date of entry of the astrolabe into England. It was in that year that Walcher of Malvern arrived from west-central Europe and settled. Walcher constructed lunar tables, and among his works is a list of data which he recorded during the eclipse of October 18, 1092. (His observations were made with an astrolabe.) By the time of his death, in 1135, he "had

[12] Pp. 113 ff. From his investigations of several MSS., Haskins states his opinion that "an acquaintance with this instrument had in some unknown way passed into Latin Europe in the course of the eleventh century, thus preceding considerably the arrival of the Arabian astronomy as a whole." (p. 115). Entry may first have been through Byzantium when the Turkish inroads on the Byzantine Empire, and the fall of Byzantium, forced many scholars west.

[13] R. W. T. Gunther. *The Astrolabes of the World.* Oxford: University Press (1932). (2 vols.) pp. 55-58, v. I.

[14] The Great Sloane Astrolabe is described by Gunther, *Ibid.*, pp. 463-5.

acquired a reputation as a mathematician and astronomer." It is interesting to read that Walcher probably learned to use Arabic numerals from one Petrus Anfusi, in England.[15] Adelard of Bath[16] was another of the early students of the sciences. He wrote on such varied subjects as his travels, Euclid, and the astrolabe. Haskins mentions the more scientific treatment in the treatise on the astrolabe (c. 1142), both in style and approach to subject matter over the earlier things Adelard wrote. "Succinct, clear, and sharp, the treatise presents in systematic form the preliminary astronomical facts and the various applications of the astrolabe."[17] Adelard went out and sought knowledge in travel and exploration. He did not consider his studies something to be limited by traditional authority; neither did he grab up new information blindly. "The first, so far as we know, to assimilate Arabic science in the revival of the twelfth century, to him we owe the introduction of the new Euclid and the new astronomy into the West." Among the men who followed the teachings of Adelard was Robert of Chester.[18] Among his writings is a treatise on the astrolabe. (London, 1147.) Robert's greatest contributions were his revisions of astronomical tables and his work in alchemy and algebra, the latter two especially important.

The history of the astrolabe between these early times and the date of Chaucer's treatise (1391) is not well known. It would seem that the works devoted to it, or at least touching upon the instrument, were translations of copies of Arabian works, or re-workings of earlier treatises. However, a notable development in the construction of astrolabes may be traced to eleventh century Spain and should be considered here. Al Zarqoli of Cordova (1029-1087) was the inventor of the "arzachel"—a horizontal projection of the sphere. This invention made the astrolabe a universal instrument, and thereby removed the necessity of having a climate plate for each location where the instrument was used. The instrument which Chaucer described in his treatise was the usual type and employed climate plates. Of the astrolabes of England which Gunther lists—fourteen—which were built before the close of the fourteenth century, only the Sloane appears to have a "universal plate."

With this information as a background we can proceed to a discussion of some of the aspects of Chaucer's treatise—"Bread and milk for little children."

IV

Chaucer, then, inherited a wealth of information on the astrolabe.

[15] *Studies in the History of Medical Science*, p. 115 ff.

[16] *Ibid.*, pp. 20-42. Haskins refers to Adelard as "the pioneer student of Arabic science and philosophy in the twelfth century, and 'the greatest name in English science before Robert Grossetete and Roger Bacon'." He is known from his writings, some of which were translations (p. 20).

[17] *Ibid.*, p. 41.

[18] *Ibid.*, p. 122.

As we have seen, the astrolabe was concurrent with, if it did not precede, the revival of learning in the eleventh and twelfth centuries. In the thirteenth century, the work of the Englishman Sacrobosco gave further impetus to the active interest in the sciences. And Chaucer contributed his bit a century later, by his own treatise—the first treatise of its kind written in English.

Chaucer's personal interests probably first led him to become familiar with the astrolabe and the literature that existed on it. His seemingly insatiable desire to find out all he could about everything he met with led him into studies that the specialized student of today can hardly imagine. An interest in astrology—it crops up often in his work—required that he learn much that was common to the astronomer as well as the astrologer. It was probably in this connection that he first encountered the astrolabe, but it was probably during his time as Clerk of the King's Works that he grew very familiar with the instrument. The journeys in France, Italy, and Flanders might have necessitated the use of the astrolabe.[19] And it is such points as these that make the astrolabe of special interest to the student. The armillary sphere, and like instruments of the period, could not be easily used in the field. In the astrolabe, we find an accurate instrument for the astronomer, required equipment for the astrologer, a necessity for the engineer, and an aid to the traveller.

The astrologer's problem was easily met by the astrolabe. The usual problem of the astrologer was to determine the position of the stars (zodiacal signs) and planets in the heavens at a given point in time and interpret what he found at the time of the observation. Star and planetary tables would give him this information, but the astrolabe would also give him this information more quickly and with much less effort. With one reading and a simple setting, the astrologer could see the positions of the signs and go to work on his horoscope. If the horoscope had to be cast for a period in the past, then a thorough man would need to spend a few hours with the tables. But, for the reading of a particular moment—say to cast the horoscope of a new-born child—the astrolabe offered the simplest solution. Many of the early writers on astrology insisted on the necessity of knowing and using the astrolabe—and well after Chaucer's day, it was considered a requirement of the intelligent physician.

But more interesting are the problems that confronted the engineer which could be solved with the instrument. (Two problems involving the use of the astrolabe will be given elsewhere in this paper.) If he did not trust his estimation by eye, the bridge builder could measure the width of a given river, and then measure the height of the selected trees to see if they would fill his needs. By using his astrolabe he also

[19] Pocket astrolabes—some less than three inches in diameter—were not unusual. A timepiece that is also useful in geographical orientation is a valuable instrument for any traveller.

determined—if necessary—the time of the next high tide in order that he might utilize his time available to the fullest. Many of the treatises on the astrolabe are more descriptions of the things that can be done in the field than anything else.

The earliest use of the astrolabe in navigation is usually credited to King John II of Portugal, who reigned from 1481 to 1495.[20] In order that he might find some method that his ships might employ to keep to a given course at sea, he employed Roderich, Joseph, and Martin Behaim of Nurenberg to study the problem. Their solution utilized the astrolabe. It is difficult to believe that this was the first instance of using the astrolable in navigation. The instrument had been pretty well exploited by the time of John II, and it does not seem likely that such an excellent use for the instrument would have remained unknown so long.[21]

Of the many operations possible with the astrolabe, we may easily examine two which will serve to indicate the versatility of the instrument and which will also show its simplicity of operation. Two common problems were determining the time and determining the height of a given tower, tree, or the like. Essentially, the operations of the astrolabe involve using the moving parts to set the data of the problem in hand and then determining the result from the information in the borders. Some operations involved interpolation between graduations marked on the borders, but these were not too elaborate for field work.

Assume that it is a fair day and the observer wishes to set the clock he has succeeded in wheedling from a rich friend who has just returned from the continent. Astrolabe in hand, he sets forth. From the position of his shadow, our observer checks to see whether it is before or after mid-day. (He must check on the general time of the day in order that he may be sure to remember which parts of his astrolabe's information he will use. Too, he remembers that he cannot "justly set a clokke" if he uses information obtained between 11:00 A.M. and 1:00 P.M.—or the corresponding hours at midnight.)[22] The observer turns his left shoulder to the sun and holds the astrolabe with his right thumb, the back half towards himself. He moves the rule until the light from the sun falls through the sights in the vanes. Then, he reads the number of degrees—the altitude—clockwise from the small cross on the east line. The observer then finds the degree of the sign of the zodiac for the day. (For instance, the degree for the 20th of February is the tenth degree of Pisces.) He turns the instrument over and sets the degree of the sun on the proper (same degree as altitude of the sun) almicantera. He then lays the label on the degree of the sun and

[20] *Encyclopedia Americana*. New York: The American Corporation (1946). Vol. II, p. 452.

[21] *Astrolabes of the World*, p. 524, v. II. The Spanish philosopher, Raymond Lully (1235?-1315), wrote of the use of the astrolabe in navigation by the Majorcan pilots as early as 1295.

[22] See: *Poet. Works of Chau.*, pp. 647-8, ll. 70-89.

reads the time in the border. If it is before noon, the degree of the sun is set in the east side of the almicanteras; if it is after noon, the setting is in the west half of the almicanteras. If before noon, the time is read in the border of the left half—one to twelve from North clockwise; if after noon the reading is on the right half of the border, reading from South clockwise. (The ascendent is read on the east side of the "horizon obliquus"—the lowest of the almicanteras—and it is that sign of the zodiac then crossing the horizon obliquus.)[23] Since each degree in the border represents four minutes of time, this determination could be quite accurate on a moderately large instrument.[24]

One of the most valuable of the features of the astrolabe was the system of shadow scales. These scales are based on a 45° right triangle. (See Figure 3.) Each scale was divided into twelve equal parts, and the constant relation of the sides made the solution of systems of right triangles—one of which would be represented in the shadow scales—quite simple. Assume that we wish to find the height of a given tower. As did Chaucer, we will assume that we measure a convenient distance—20 feet—from the base of the tower. From this point, we measure the angular height of the tower with the rule. In this case, assume that we read in umbra recta the number "4." We then know that the distance from the observer to the base of the tower represents four-twelfths (one-third) of the height of the tower; in this case the altitude of the tower is found to be 60 feet. If the base of the tower were inaccessible, a procedure employing the umbra versa was used. This involved two readings on the tower and a known distance between the points of reading. In either case, the eye-level height of the observer was added to the computed height.

As we have seen, these are merely two of the operations which were performed with the astrolabe. (An enterprising gunner could have used the instrument as a range-finder in much the same way as would the engineer in determining distances.) Centuries later, instruments of the engineer — and the astronomer — embodied the use of the telescope, but the problem and its solution were much the same.

[23] The procedure at night is much the same, and involves observations on a fixed star. It may be summarized as follows:

1. Take altitude of a star represented on rete.
2. Note degree of sun for that day.
3. The center (point of projection which represents star) of the star is laid in the almicanteras on the observed altitude. (West almicanteras.)
4. Lay the label over the degree of the sun and read the time in the border.
5. The ascendent may be read from the east horizon.

[24] Existing astrolabes of the XIV century range in size from "pocket models" to instruments large enough to require some method of suspension—or a very strong arm. The Great Sloane Astrolabe is 18.25 inches in diameter, 7/16 inch thick, and weighs 30 pounds. Another instrument (c. 1300-50 is only 3 and ⅜ inches in diameter and 3/16 inch thick. In the history of the astrolabe in all countries and ages, we find examples that range from the astrolabes of India which were sometimes as much as seven feet in diameter to a miniature instrument that formed the crest of an Italian ring. Folding pocket models were quite usual in the centuries following that of Chaucer.

Only in the prismatic astrolabe does the name still survive today. The plane-table—"forecast" in the astrolabe—is still considered an effective field expedient in sketching terrain. An interesting device of today which is reminiscent of the astrolabe—insofar as measuring unknown sides of triangles is concerned—is the Critchlow slide rule, one of many types of circular slide rules. (The Critchlow is based on logarithms and is used to solve right triangles.)

Thus, we find the astrolabe doubly important in medieval life. It was an instrument for the scientist who was involved in work of a more theoretical nature and the "man on the ground" who had material problems he wished to solve as quickly as possible. This factor—perhaps as important to Chaucer as Lewis' interest in the instrument—led to his writing a treatise and writing it in English.

V

We do not know how many treatises Chaucer knew at the time he began work on his *Astrolabe*. Of the many writings he knew were those of Messahalla, Sacrobosco, and Daniel of Morley. There were probably others which have not yet been identified. The treatise—compared to the poet's other work—has been neglected by students of Chaucer. However, Chaucer's dependence upon Messahalla was early recognized, although it has not yet been thoroughly evaluated.

Little is known of the circumstances of Messahalla's life. Gunther[25] calls him "one of the earliest astronomers of Islam." It is believed that he lived in the late eighth and early ninth centuries, "the renaissance of Arabian science and art." He is remembered for his *Compositio et Operatio Astralabie*, one of his many and varied works. Messahalla was a Jew whose homeland was Egypt. He went east, and was taken into service of Al Naubakht, the Persian. While with Al Naubakht, he made the preliminary survey of the site of Bagdad, which was founded in 762-763. In sharp contrast with this side of Messahalla, we find that there is a text attributed to him on the prices of merchandise—the earliest Arab text on that subject.

That Chaucer should have been interested in Messahalla's treatise over others he knew may be due to any number of considerations. Messahalla's treatise is quite lucid in its description of the actual making of an astrolabe. However, no one has yet taken several manuscripts (of different authors) on the astrolabe and attempted a critical comparison. Such a study could throw much light on Chaucer's choice, and on the literature of scientific instruments of the period. Some work in the investigation of sources has been done with the result of demonstrating some interesting points in Chaucer's method,[26] if not in his selections taken from other authors. Mr. Harvey cites one instance where

[25] *Chaucer and Messahalla on the Astrolabe.*

[26] S. W. Harvey, "Chaucer's Debt to Sacrobosco," *Journal of English and Germanic Philology*, Vol. XXXIV, January, 1935. Urbana: University of Illinois Press.

gation of Chaucer's *Astrolabe* to attempt to determine whether the poet's approach to this problem was the same as that he employed in his poetry—free and extensive, yet intelligent and creative, use of the works of other writers. But before considering his findings, a word or two on Sacrobosco are necessary.

"Sacrobosco" is the Latinized name of John of Hollywood. Generally, he was known as Johannis de Sacrobusco (or, "Sacrobusto"). Of his life and career, again, we know little. Delambre[27] tells us that he was not an astronomer, but rather a learned man who was interested in a revival of interest in astronomy. His *Sphaera Mundi* is probably the best known of his works, although he wrote on other subjects as well. Interest in astronomy, especially as handed down in the *Almagest*, led to his writing an abridged version of the astronomical material in Ptolemy's great work. This abridgment, *Sphaera Mundi*, was the earliest work on astronomy produced in Europe.[28] Sacrobosco's work gave rise to a series of commentators, the best known being Clavius. Sacrobosco lived and worked in the first half of the thirteenth century, but his work was quite important to the European scholar for centuries.

The close relation of Chaucer's treatise to that of Messahalla was soon discovered and examined. Skeat's edition of 1872 had devoted much space to a discussion of this relation and even included the Latin of the second part—"Operatio"—of the Messahalla treatise. It was also early noted that Chaucer had relied on Sacrobosco to some extent, but the assumption was that the influence of Messahalla far outweighed that of any other writer. This assumption was based on identification of certain specific points from Messahalla, especially in the "conclusions," and assuming that the parts in between these noted points were paraphrases or the like from the *Compositio et Operatio*. Harvey has shown that this is not the case. To illustrate the results of his investigation, Harvey points out that many lines, formerly attributed to Messahalla, were taken directly from another author—more often Sacrobosco than anyone else. For example, Section 17 of Part I of Chaucer's *Astrolabe* was shown by Mr. Harvey to consist of seven lines from Messahalla, thirty-nine lines from Sacrobosco, and nineteen which appear to be original. Mr. Harvey notes that the borrowings from Sacrabosco are more direct—often literal translations. Chaucer's paraphrasing is "extraordinarily close to the original."

Among the borrowings from Messahalla and Sacrobosco are surely selections taken from other authors. Mr. Harvey cites one instance where

[27] J. L. B. Delambre. *Histoire de L'Astronomie du Moyen Age.* Paris: Courcier (1819). "Sacrobosco et ses Comentateurs," p. 241 f.

[28] *Ibid.*, p. 241. "Le plus ancien ouvrage d'Astronomie que l'Europe ait produit, ou qui nous soit parvenu, est la Sphere de Sacrobosco . . ." Delambre also lists the name "Jean Halifax," another of the names by which the scholar was known.

a bit from Daniel of Morley[29] is inserted between two passages taken from Sacrobosco. Such evidence indicates that Chaucer carried the borrowing method of his poetry over into his *Astrolabe*. This reliance on older authorities is to be expected and further work in identification of these authorities should be as enlightening as similar investigations of his poetic works have been.

From these points, we may draw certain conclusions about Chaucer and his *Astrolabe*. We know that the astrolabe was an ancient instrument and many scholars had written on it long before our poet decided to take up the problem. We find that Chaucer chose Messahalla's treatise as a basis and borrowed freely from other sources. (Mr. Harvey sees Chaucer using Messahalla's work for a frame on which he hangs passages from Sacrobosco, and perhaps others.) We still do not know how deeply Chaucer had gone in astronomy, but he had more than a casual interest. He knew the works of Sacrobosco and Daniel of Morley, both of whom probably knew trigonometry. Chaucer had served in capacities requiring a knowledge of, or at least familiarity with, the problems of civil engineering. He had travelled in Italy, France, and Flanders, and may have been acquainted with some of his continental contemporaries who were working in astronomy and the related sciences. The poet may have known some of the men then engaged in work in astronomy and the instruments they used at Oxford. For example, the "Merton astrolabe" is one of the few surviving and most interesting of the English instruments of the fourteenth century. It is unique in its construction.[30] It was primarily a planetary astrolabe —one used in working out problems involving the planets. Chaucer may have known this instrument; Lewis Chaucer was at Oxford and the poet's treatise describes an instrument made for the latitude of Oxford.

Chaucer outlined a monumental task for himself when he described in his preface the proposed extent of his treatise. It was no more than many had done before him, but it was an elaborate plan and one which would have taken quite some time to complete. Of the five proposed parts, only two were completed, and there are many questions unanswered about the portions which we know. At best, only two of the parts are in a final stage. The first part is a description of the instru-

[29] Daniel of Morley was a student at Paris and, later, at Toledo. He was much interested in the sciences as they were taught in Toledo and felt the work going on there to be superior to that in Paris. His *Liber de naturis inferiorum et superiorum* quoted by Mr. Harvey was written on his return to England "to explain the teaching of Toledo to Bishop John of Norwich (1175-1200) . . ." See: *Stud. in the Hist. of Med. Sci.*, pp. 126 f.

[30] *Astr. of the World*, pp. 472-4. The Merton has two projections ("ears"), fitted with vanes perforated to be used as sights, which are close to and equidistant from the thumb-ring post. At the base of the left ear on the front half is a rivet and eyelet to which was attached a plumb line for working with a quadrant scale on the instrument. A small projection at the bottom of the instrument —an extension of the north line—was perforated to take a loop holding weights to steady the instrument when it was being used. The instrument does not have the usual raised border, but this feature is shared by other instruments.

ment, and the second is a series of problems, or "conclusions." This much was completed. The third part—a series of tables, the fourth—"to declare the moevyng of the celestiall bodies with the causes" and more tables, and the fifth—"the general rewles of theorik in astrologie" with more tables, were never written. The parts that were finished offer the student a convenient and simple introduction to the instrument. This is apparently what the author intended. But, the proposed treatise would surely have been a healthy bit for Lewis at his "tendir age of ten yeer." In considering the treatise we must remember that it was designed to accompany an instrument which the author had in mind. The MSS. were illustrated with sketches of the parts which were described. We must remember that it is only two-fifths of the original plan, and must be judged as a fragment.

The introduction to the treatise has been of great interest to the student of Chaucer, although the rest of the work seems pretty largely ignored. The identification of the "Lewis" of the introduction has been a problem much bandied about, and only reluctantly do the historians seem to grant that Chaucer could have had a son named Lewis. The literary merits of the introduction are numbered by Robinson: "It is a short specimen, but it indicates that if Chaucer had written any considerable amount of freely composed prose it would have been superior in form to the *Boece* and the *Melibee*."[31]

To the student of Chaucer, a study of the *Astrolabe* is doubly stimulating. Such a study points out new and interesting phases of fourteenth century life which he may never have suspected. More important, perhaps, such a study gives a greater insight into the mind of the man who wrote the *Boece* and the *Troilus*. The work indicates the poet's varied and honest interest in the world around him, and the greatness of his mind. He was not a scientist and did not profess to be one. Chaucer writes in his introduction: "I n'am but a lewd compilatour of the labour of olde astrologiens, and have it translated in myn Englissh oonly for thy doctrine." But in this 'compilation' he has left a great heritage for the student of the history of English science and Chaucerian lore.

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The Paradox of the Foucault Pendulum

By PAUL E. WYLIE

The motion of the Foucault pendulum affords an irrefragable proof of the rotation of the Earth. In many places, such pendulums are in operation, so that one may actually see the Earth's rotation. This proof is not overlooked in astronomical texts. The demonstrations of the theory of the pendulum in most texts are, however, incomplete; indeed, statements are often made which lead to a paradox which remains un-

[31] *The Poetry of Chaucer*, p. 461.

resolved. It is the purpose of this article to resolve this paradox. For completeness, and to provide references, the development of the law of the pendulum is first undertaken; then the paradox is stated; and, finally, the paradox is resolved.

The Foucault pendulum consists simply of a long and heavy pendulum, without any attachments or mechanical sources of force whatever, which is set in vibration by pulling it to one side and then releasing it. As long as it remains in motion, it will show the rotation of the Earth by the skewing of the local meridian in reference to the plane of vibration of the pendulum. The law of this relative motion will be developed by reference to Figure 1, which represents the Earth, (assumed to be spherical). P_n is the north pole; R, the Earth's radius; r, the radius of the parallel of latitude of the observer, who is located at E, in latitude ϕ; dt, the elapsed sidereal time, expressed as arc.[1]

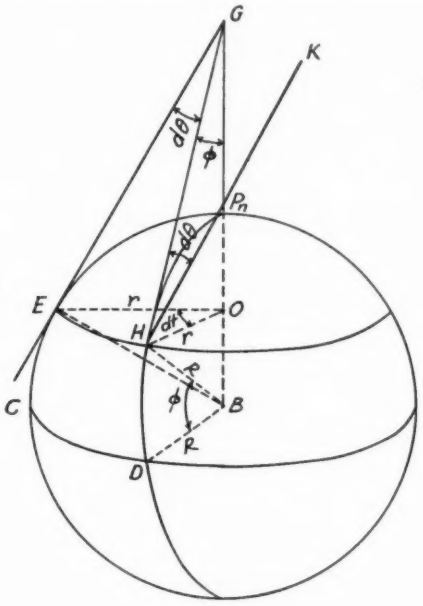

FIGURE 1

At a given instant, when the observer's meridian is in the position P_nEC, a pendulum, subject to no force except gravity, is set vibrating in the plane of that meridian. The trace of the pendulum—the vertical projection of its arc of vibration on the horizon—is the line EG, which intersects the extension of the Earth's polar axis in the point G. G is, of course, also the point where the horizon plane, tangent to the Earth at E, intersects that axis. Leaving the pendulum in vibration, allow a

time interval dt, expressed in arc as the angle EOH, to elapse. This angle dt, or EOH, is an infinitesimal, approaching zero as a limit; it is smaller than any finite quantity we may choose to name. At the end of the time interval dt, the direction of the plumb line—and hence, since they are perpendicular, the horizon—will have moved through the angle EBH.

If dt is small enough, EH may be considered as an arc of the circle with radius HB, as well as an arc of the circle with center at O, since both of these lines approach the same straight line in the limit. If the angles are in radians, then $EH = r\ dt$ and $EH = R \times$ the angle EBH. But $r = R \cos \phi$. Substituting this value of r and equating the two values of EH, we obtain $\cos \phi\ dt =$ the angle EBH. Since dt approaches zero at the limit, and since $\cos \phi$ cannot exceed 1, the angle EBH also approaches zero, and the horizon at E and H may be regarded as coincident, as may be the corresponding directions of the vertical. Since the force of gravity is, throughout the interval, always exactly in the plane of the pendulum's motion, and since in the limit that plane has not changed, and since the force of gravity is the only force acting, there can be no component of force perpendicular to the trace of the pendulum, and it will therefore be found at the expiration of the interval dt parallel to the original direction EG: that is, in the line HK. It is important to note that the parallelism of EG and HK is valid only in the limit, or in circumstances (which appear only at the Earth's poles) in which the horizon does not change its direction relative to the stars with lapse of time. The observer's meridian has, during the interval, moved through the central angle dt. The tangent to that meridian will have moved through the angle $d\theta$ at G. The trace of the pendulum will have moved, relative to the projection of the meridian on the horizon (at H), through an equal angle $d\theta$, since angle EGH and angle GHK are alternate interior angles in a plane, between parallel lines cut by a transversal.

It is required to evaluate $d\theta$, the angle through which the meridian has moved relative to the trace of the pendulum, in terms of the interval dt. The angle HGO = the angle HBD, since the legs of the two angles are respectively perpendicular. The latter angle is by definition the latitude, ϕ, of observation. EH may, in the limit, be considered as an arc of the sector EOH as well as of the sector EGH, since both arcs approach the same straight line as a limit. As a consequence, if $d\theta$ and dt are in radians, $EH = HG \times d\theta$, and $EH = r \times dt$. In the triangle GHO, $HG = r/\sin \phi$. Substituting this value of HG, equating the two values of EH, and solving for $d\theta$, we find: $d\theta = dt \sin \phi$, or, to give θ and t finite values, $\theta = t \sin \phi$, which is the law of motion of the meridian relative to the trace to the pendulum in the horizon. In 24 hours this angle will be $\theta = 2\pi \sin \phi$, and the time for a complete circuit of the trace of the pendulum about the meridian, in the plane of the horizon, will be 24 hours/sin ϕ. The conclusion is that the trace of

a pendulum set swinging in the meridian at the beginning of a day, will not be found in the meridian at the end of that day, except at the pole, where $\phi = 90°$. It is important to recognize that the law $\theta = t \sin \phi$ involves only relative conditions in the horizon; that is, the relative positions in the horizon of the projection of the meridian and the trace of the pendulum. The relation is purely planar; the plane involved is the horizon, however the position of that plane may change relative to the stars.

In the following discussion, let us define "direction" as absolute direction: that is, direction relative to the stars, which are assumed to be fixed and infinitely distant. If relative direction is meant, it will be specified.

It is often stated: (a) that the pendulum, once set in motion, continues thereafter to swing always in the same plane; and (b) that the trace of the pendulum on the horizon maintains a constant direction. If these statements are true, then the law of the pendulum is false. For example, if the trace of the pendulum, or the corresponding arc of its swing, maintains a constant direction, then a pendulum set swinging at the beginning of the day in the meridian would, at the end of that day, again coincide with the meridian, since the meridian's direction is the same at the beginning and at the end of the day. The law of the pendulum and experiment agree that it does not coincide. It remains to resolve this paradox.

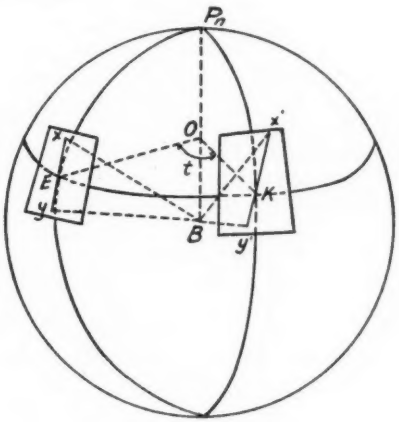

FIGURE 2

That statement (a) is false is shown in Figure 2, which shows the horizon, the pendulum trace, and the meridian at the beginning and at the end of a time interval of about 2 hours. At E, we have the same situation as at E in Figure 1. The pendulum trace, xy, lies in the meridian. The plane of vibration is xBy. At K, the pendulum trace x′y′

is in the horizon, making an angle t sin ϕ with the meridian. The plane of vibration is x′By′, which is obviously quite different from the plane xBy at E. We may at once say that statement (a) is false: the pendulum does not swing in an invariable plane.

Passing now to statement (b), we may say that the pendulum itself does not trace out a line of invariable direction, whether its arc or its horizontal trace be considered. It swings symmetrically (damping neglected) about the direction of gravity. Since this direction of gravity, as has already been shown, is changing, so does the direction of swing change conformally. The trace may be defined as a line perpendicular to the vertical at the surface of the Earth in the plane of the swing. This is a line in the horizon, but since the plane of the horizon is constantly changing direction both north and south, and east and west, it cannot be a line of constant direction. The change in the direction of the trace may be compared to the track of a wheel on the Earth, which may move back and forth, always remaining vertical, but may not skew. Skewing would involve a force outside the plane of the wheel—and there is none. The skewing is done by the Earth beneath the wheel.

The fact that the trace of the pendulum does not move parallel with itself may be somewhat more conclusively demonstrated by consideration of Figure 2. If the horizon planes at E and K be extended, they will intersect in a line that passes through G (Fig. 1). A theorem of geometry states, substantially: A line in one of two intersecting planes is parallel to a line in the other plane only if both lines are parallel to the line of intersection of the planes. In the current case, both xy and x′y′, if sufficiently prolonged, will intersect the line of intersection of the two horizons, and therefore cannot be parallel to it or to each other. Moving xy from its unique place in the meridian serves only to shift the point of intersection, and therefore does not affect the argument. From what has been said, it is proved that statement (b) is false; the pendulum is under no logical necessity to return to its original position at the end of each day. It is sufficient if it conforms to the law.

This conclusion may be reinforced by a consideration of the daily motion of the meridian. The projection of the meridian on the horizon is a line such as EG or HG in Figure 1. If all such lines are considered, a cone of slant height EG and base radius r will be generated in a day, the lines described being elements thereof. Any given element will describe on the celestial sphere, if extended, in the course of a day, the "circle of perpetual apparition:" a small circle of the celestial sphere, of radius ϕ. This fact suffices to show that the direction of the meridian is variable. The circumference of the base of the cone $= 2\pi r$. (See Fig. 1.) If the cone be developed into a flat sheet, this distance is equal to HG $\times \theta$, where θ is the total angle around the vertex G. HG $= R/\tan \phi$, and $r = R \cos \phi$. Substituting, we obtain

$$\frac{R\theta}{\tan \phi} = 2\pi R \cos \phi;$$

that is, $\theta = 2\pi \sin \phi$. From this it appears that the changes in the direction of the pendulum trace are introduced by the erection of the cone; if the cone could be reduced to a plane, then the direction of the pendulum trace would be invariable. We shall return to this situation later.

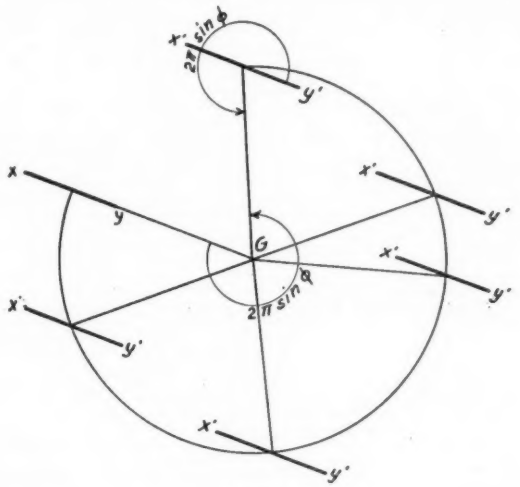

FIGURE 3

Figure 3 shows the developed cone. This plane shows the "plane" in which the law of the pendulum was derived. The radii are the elements of the cone. The short lines are representative traces of the pendulum. It is seen that these traces are parallel. Only if the developed cone comprises a full circle (which it cannot do and remain a cone) can the pendulum trace coincide with the meridian both at the beginning and at the end of a day. Only at the pole may such a condition be found; there, the cone is depressed so that its vertex coincides with the center of its base; it is a point, or, if the directions of the elements be conserved at the limit, a plane. If, then, the pendulum is moved to the pole, the horizon becomes a plane of constant direction—stationary. The pendulum trace becomes there a line of invariable direction in the horizon, and the projections of the meridians merely rotate under the trace, like the spokes of a wheel, in a period of 24 hours.

At the equator, the cone becomes a cylinder. The direction of the meridian is invariable. Since, in other latitudes, it is the change in the direction of the meridian that causes relative motion between the trace and the meridian, and since such a change of direction is absent at the equator, the trace of the pendulum there will forever remain unchanged, relative to the meridian.

For simplicity, we have limited discussion to a pendulum started in

vibration in the plane of the meridian. The discussion suffices, however, no matter what may be the initial direction of vibration. We need wait only until the trace of the pendulum started in the meridian shows the same azimuth as the one to be started in some other direction. Thereafter, if the second pendulum is started in motion at this time, the two pendulums will be indistinguishable, and the discussion of the motions of the one will apply unchanged to the motions of the other.

REFERENCES

[1] For the non-mathematical reader: dt and $d\theta$ do not indicate products of factors, but merely vanishingly small values of t and θ, respectively. Other readers will readily transform the discussion into a straightforward integration.

[2] The author expresses his thanks to Dr. F. C. Leonard for his critical reading of the manuscript.

DEPARTMENT OF ASTRONOMY, UNIVERSITY OF CALIFORNIA,
LOS ANGELES, CALIFORNIA, FEBRUARY 12, 1949.

Two New Families of Comets

By C. H. SCHUETTE

For many years it has very well been know that the periodic comets are divided into several families, which show an evident relationship with the great planets. This is most obvious when the comets are arranged according to the distances of their aphelions. The number of the discoveries, also of the periodic comets, has considerably increased in recent years, and several comets were found at their second apparition, so that at present we have knowledge of more than 40 comets which have been observed in at least two apparitions. Thus the number of well-known orbits has increased and, therefore, I was interested in a new discussion. After all, the family of the comets of Jupiter includes the majority of them and, with more than 50 members, is the best known.

We will divide all comets into two groups, *viz.*, those that have been observed in several apparitions, and those that have been observed in only one apparition. Thus we get the distribution shown in Table I with the mean values of the most important elements of their orbits.

The most important facts of the families agree perfectly in both groups and may be expressed as follows:

1. The distances of the aphelions group around the aphelion of the corresponding planet, so that in general the mean distance of the aphelions of each cometary family is somewhat greater than that of the planet. Only the family of Uranus shows a mean distance of the perihelion which seems to be a little smaller than that of the planet; but this is of no importance, the Uranus-family being the smallest.

2. The directions of the aphelions, at least in the mean of the Jupiter's family agree closely with the direction of the aphelion of the planet. In the first group we find the difference to be $+9°$, and in the

TABLE I

GROUP I. 39 COMETS WHICH HAVE BEEN OBSERVED IN MORE THAN ONE APPARITION

Family No.	Periods	Mean distances of aphelions	Mean perihelion of Comets —perihelion of planet	Mean inclin.	Mean eccentricity
— 1[1]	3y.3	4.1	—	12°6	0.85
Jupiter 26	4.9 — 8.5	5.54 (5.45)	+ 9°	14.1	0.58
Saturn 4	11.0 —18.0	10.4[3] (10.1)	—103	22.8	0.62
Uranus 2	27.9 —40.1	19.8 (20.1)	— 86	23.6	0.89
Neptune 6	49.1 —76.0	31.6 (30.3)	+ 75	35.2[2]	0.93

GROUP II. 31 COMETS WHICH HAVE BEEN OBSERVED IN ONLY ONE APPARITION

Jupiter 26	4.5 —10.9	5.77 (5.45)	— 6°	11°7	0.65
Saturn 2[4]	13.4 —16.4	11.4 (10.1)	+ 8	54[2]	0.83
Uranus 1	33	19.6 (20.1)	—130	17[2]	0.90
Neptune 2	75.7 —79.5	35.8 (30.3)	+ 80	54	0.95

The number in ( ) gives the distance of the aphelion of the corresponding planet.

Notes: [1]Comet Encke. [2]For retrograde orbits 180°—i is given. [3]If comet Schwassmann-Wachmann I is included, we obtain 9.6. [4]Here the uncertain comet 1916 II (Perrine) which was observed only one day is included.

second —6°. In all other families this peculiarity is not so evident, on account of the small number of their members. Figure 1 shows the distribution of the aphelion points of all 52 comets of both groups of Jupiter's family.

3. The mean inclinations of orbits of the families increase with increasing distance from the sun.

4. The eccentricities increase also in the same manner.

Whatever may be the origin of these facts, there is no doubt of a relation between the families of the comets and the corresponding great planets. Moreover, the predominance of the Jupiter-family, caused by the dominating great mass of this planet, is very clear.

The last comet of the Neptune-family is the comet 1921 I (Dubiago) with a period of revolution of 79.51 years and a mean distance of 18.5 from the sun. Dubiago himself, who also calculated its orbit, pointed out that this comet is a new member of the Neptune-family (*Astron. Nachr.*, **222**, 111). Of all the above-mentioned comets this one has the greatest period and the greatest aphelion distance.

Besides the Neptune-family there is a great number of periodic comets with long periods of revolution which up to now have scarcely been discussed as to their families. The discovery of Pluto, the fact that two of these comets were identified with former comets (Comet 1939 VI, Rigollett, = 1788 II and Comet 1907 II, Grigg-Mellish, = 1742), and the fact that in 1931/32 there were discovered four new periodic comets with greater periods, whose orbits could be determined with relatively great accuracy, have led me to discuss these orbits once more on account of their families.

Considering all comets with great eccentricities and great periods of revolution, it may be noteworthy that after the last above-mentioned

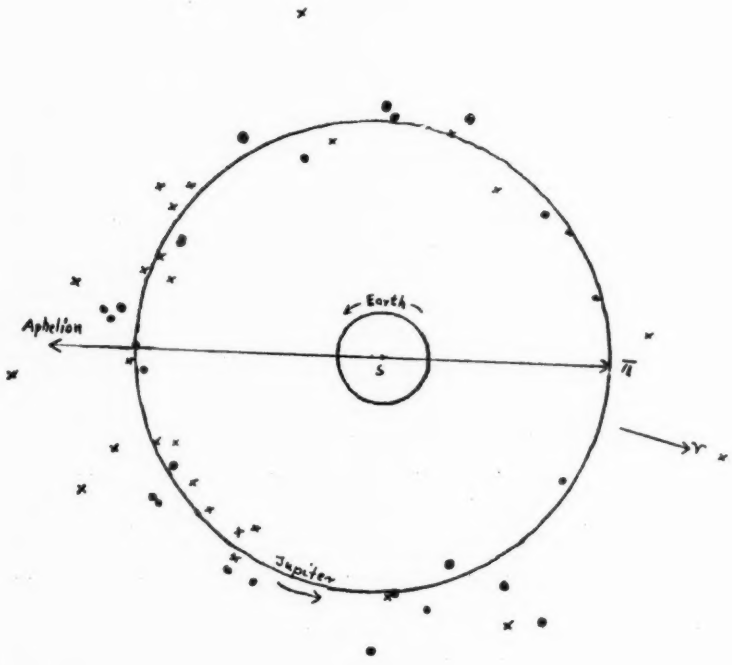

FIGURE 1
DISTRIBUTION OF THE APHELIONS OF 52 COMETS OF THE JUPITER FAMILY
(Circles denote comets observed at 2 apparitions or more;
crosses those observed at one apparition only.)

comet of the Neptune-family (Comet 1921 I, period 79.5 years) there is no comet up to a period of nearly 120 years, *i.e.*, we have no comets between the mean distances from 18.5 to 24. On the contrary, in the space from the mean distances of 24.2, to 30.0 we find five comets. From 30.0 to 38.0 there is a gap without any comets, but in the interval from 38.0 to 45.4 there are another eight comets. This seems to be a striking accumulation around these two regions; and it is very interesting to consider these two families that may be called the Pluto and Trans-pluto families. The most important elements of both these families may be seen from Table II.

TABLE II

Table of the elements of the orbits of 13 comets of the Pluto and Transpluto families.

No.	Name	T = Perihelion Passage in G.M.T.	Period in Years	Distances of Perih.	Aph.	Arc from Asc. Node to Perihelion	Longitude of Ascending Node	Inclination of Orbit to Ecliptic	Eccentricity	Reference
				Pluto Family						
1	1862 III Tuttle-Swift	Aug. 22.9	119.6	0.9626	47.6	24.28	152°.76	137°.45	113°.57	0.96035	Yamamoto 294
2	1889 III Barnard	June 20.7	128.2	1.1024	49.8	25.44	60.14	270.97	31.21	0.95667	Yamamoto 406
3	1917 I Mellish	April 10.7	145.3	0.1902	55.0	27.62	121.30	87.53	32.68	0.99312	Yamamoto 544
4	1939 VI Rigollet[1]	Aug. 9.5	156.1	0.7485	57.2	28.99	29.30	355.13	64.20	0.97418	*VJS* **76**, 32
5	1907 II Grigg-Mellish[2]	Mar. 27.2	164.3	0.9233	59.0	29.96	328.43	189.23	109.84	0.96918	Yamamoto 496
				Transpluto Family						
1	1857 IV C. H. F. Peters	Aug. 24.0	234.6	0.7468	75.3	38.04	180.96	200.82	32.77	0.98037	Yamamoto 272
2	1932 X Dodwell-Forbes	Dec. 30.5	262.1	1.1308	80.8	40.96	327.34	77.67	24.50	0.97239	*VJS* **72**, 115
3	1931 III Nagata[3]	June 11.6	267.5	1.0449	82.0	41.50	319.96	191.32	42.33	0.97482	*VJS* **68**, 79
4	1885 III Brooks	Aug. 10.2	274.5	0.7491	83.7	42.23	42.86	204.76	59.11	0.98226	Yamamoto 382
5	1905 III Giacobini	April 4.1	297.2	1.1152	88.0	44.54	358.24	157.38	40.24	0.97496	Yamamoto 484
6	1932 I Houghton-Ensor	Feb. 28.9	302.0	1.2544	88.7	45.04	303.52	212.53	74.28	0.97215	*Nachr. Bl. Astr.* 7, 15
7	1932 V Peltier-Whipple	Sept. 1.9	302.5	1.0372	89.1	45.06	38.47	344.52	71.72	0.97698	*VJS* **69**, 121
8	1874 IV Coggia	July 17.7	306.0	1.6880	89.1	45.41	149.60	215.85	34.14	0.96283	Yamamoto 340

[1] L. E. Cunningham suggests identity with 1788 II.
[2] Probably identical with 1742.
[3] Crommelin suggests identity with 574 and 1092 (*M.N.*, **92**, 309).

The mean values of these elements, corresponding to those values of the groups I and II given in Table I are:

GROUP III. 13 COMETS OF THE PLUTO AND TRANSPLUTO FAMILIES

Family	No.	Periods y	Mean distances of aphelions	Mean Perihelion of Comets —perihelion of planet	Mean inclinat.	Mean eccentricity
Pluto	5	119.6—164.3	53.7 (49.3)	+51°	53°	0.9707
Transpluto	8	234.6—306.0	84.8 (?)	(?)	47	0.9746

There may be mentioned some remarkable facts.

Family of Pluto: The first and last comets have retrograde motion and all have very great inclinations of their orbits. The two last comets have been observed in two apparitions, but the others have not been observed after their discovery.

Family of Transpluto: All comets are direct, and the inclinations of their orbits are great. This family has doubled by the discoveries of 1931 and 1932 and is divided into two groups with nearly the same longitude of perihelions (about 24° and 154°) and one individual comet. But having very different inclinations of orbits, any identity of the orbits of each group is not possible.

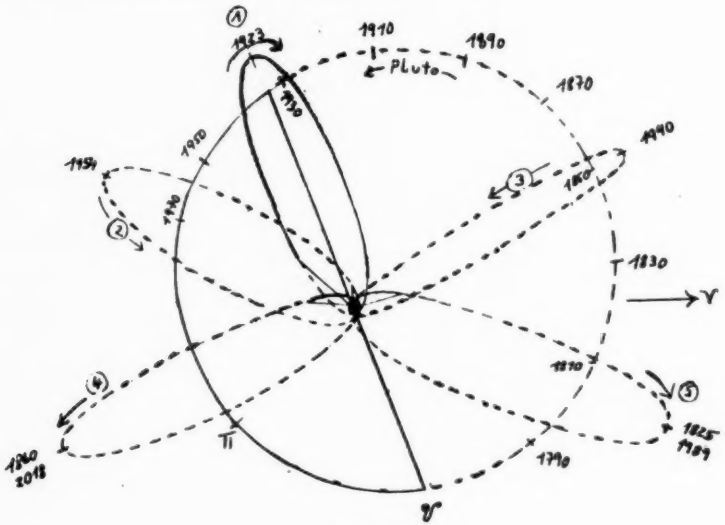

FIGURE 2

1 = Comet 1862 III (Tuttle-Swift); 2 = Comet 1889 III (Barnard); 3 = Comet 1917 I (Mellish); 4 = Comet 1939 VI (Rigollet) 1788 II; 5 = Comet 1907 II (Grigg-Mellish) 1742.

In order to get a clear view of both these families Figures 2 and 3

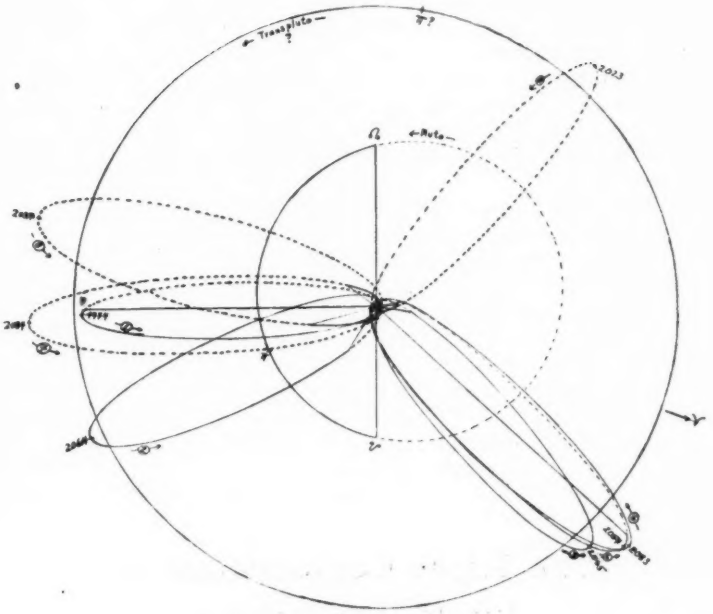

FIGURE 3
EIGHT COMETS OF THE TRANSPLUTO FAMILY
1 = Comet 1851 IV (C. H. F. Peters); 2 = Comet 1932 X (Dodwell-Forbes); 3 = Comet 1937 III (Nagata); 4 = Comet 1885 III (Brooks); 5 = Comet 1905 III (Giacobini); 6 = Comet 1932 I (Houghton-Ensor); 7 = Comet 1932 V (Peltier-Whipple); 8 = Comet 1874 IV (Coggia).

are drawn. No regard for inclination of the orbits has been taken, but those parts of them that are south of the ecliptic are dotted.

What are the consequences of the existence of both these families? There is no doubt that the Pluto family confirms anew the fact of families under the influence of a great planet. The existence of a Transneptunian planet was suspected by several astronomers on account of the Comets 1862 III and 1889 III. Although the five comets of this family were known before the discovery of Pluto, nobody seems to have had the idea that this great family announced very positively the planet Pluto.

If we consider all the families as caused by the action of the great planets, then we should do the same with the eight comets of the Transpluto family. There must be a new planet, a Transpluto, that has created this family. After the well-known law of Titius-Bode the new planet has probably a mean distance of 77.2 astronomical units from the sun. Therefore a circle with the radius of 77.2 units is drawn in Figure 3, and we see that the mean distances of the aphelions of the

comets of this group are in agreement, in that they are somewhat greater than the circle, in the same manner as has been pointed out for the other families. It is very remarkable that the planes of the orbits of this family arise above the ecliptic in the same direction, so that the orbit of Transpluto may probably also have a great inclination; the longitude of its perihelion may be near 100°, if we suppose the difference between the mean of the cometary aphelions and that of the planet to be 0°.

Whether it is possible to determine the orbit of Transpluto by the aid of its perturbations of Uranus, Neptune, or Pluto may be very doubtful. Soon after the discovery of Pluto, E. W. Brown and others maintained that the outstanding discordances of Uranus on which the prediction of Lowell are based cannot be attributed to the perturbations of that planet. The new planet Transpluto will probably be so faint that its discovery may only happen by chance.

Investigating the orbits of the further comets at greater mean distances from the sun, we find about 40 comets with periods of revolutions up to 10,000 years, but there is no sign of any family.

MUNICH, GERMANY, ORTNITSTRASSE 15.

The Triple Conjunctions of Jupiter and Saturn

By J. STEIN S.J.

On the occasion of the 1940 triple conjunction of Jupiter and Saturn, the writer published a short paper in POPULAR ASTRONOMY (November, 1940), calling attention to the remarkable conjunction of the two giant planets in the year 1563. This note will now be amplified and supplemented.

Riccioli in his *Almagestum Novum* (I, 676) erroneously contends that the conjunction of 1563 was a *triple* conjunction, that is, a conjunction of Jupiter and Saturn which occurs three times in the same year. Calculating the epoch of conjunction by means of Neugebauer's chronological tables, we find that heliocentric conjunction occurred on November 1, 1563, the heliocentric longitude of the two planets[1] then being $L = 117°$ and the heliocentric longitude of the earth being $E = 49°$. According to the well-known criterion, however, a triple conjunction is possible only when $L - E < 30°$, and consequently such a conjunction did *not* take place in the year 1563. As a matter of fact, no triple conjunction of Jupiter and Saturn occurred during the whole interval from 1425 to 1682-1683.

[1] Incorrectly said to be the longitude of the *sun*, in line 9 of the original paper, POPULAR ASTRONOMY, **48**, 481.

But in another respect the geocentric conjunction of 1563 was most remarkable. Riccioli informs us that the conjunction was observed by Franciscus Junctinus[2] in Orange, France, on August 24, "hora 14, 30′ post meridiem," when Jupiter, more to the north, had almost entirely occulted Saturn ("cum Jupiter borealior totum pene Saturnum tegerat"). Calculating the geocentric longitudes λ and latitudes β for August 23 and 24, 1563, we find (with the hours reckoned astronomically from Greenwich mean noon):

			λ Jup.	λ Sat.	β Jup.	β Sat.
August	23	14^h	118°.85	118°.87	+0°.31	+0°.20
	24	0	118.93	118.92	0.31	0.21
	24	14	119.03	118.98	0.31	0.20

According to this calculation, the conjunction in geocentric longitude took place on August 23 at 21^h, *i.e.*, on August 24 at 9 A.M., in ordinary civil time. (It must be remembered that Neugebauer's tables give only two decimal places; consequently, the result of our calculation may be in error by 0°.01 or 0°.02, which corresponds to an uncertainty of 5 or 10 hours in the epoch.) At the time of geocentric conjunction, the difference in latitude of the two planets (or their apparent angular distance from each other) amounted to only one-tenth of a degree, and, on account of the brightness of both planets but especially of Jupiter, it must have been practically impossible to separate them with the naked eye, especially during the daytime.

To this original paper, the Editor of POPULAR ASTRONOMY added the following prefatory note: "It will be noticed that there is not complete agreement between the dates of earlier triple conjunctions cited in this paper and those given by Professor Willard H. Garrett in the preceding issue (October, 1940). Some one with the necessary time and inclination may wish to attempt to reconcile the dates given or to establish entirely different ones." No further correspondence having been possible on account of the war, the writer was unable to communicate an answer, and since in the meanwhile nobody else has come forward to explain the discrepancy, he takes the present occasion to clear up the misunderstanding.

In the paper of October, 1940 (POPULAR ASTRONOMY, **48**, 411), entitled "An Unusual Conjunction," Professor Garrett mentions the triple conjunction which occurred on May 22, October 8, and December 2 of the year 6 B.C., joined by the planet Mars in the following year. Then he continues, on the authority of Edersheim ("Life and Times of Jesus"): "The merit of first discovering these facts belongs to the great Kepler, who was led to the discovery by observing a similar conjunction in 1603-4." The ambiguity lies precisely in the word *similar*.

[2] Franciscus Junctinus, Sacrae Theologiae Doctor, of Florence, born March 7, 1523, published in 1574 his *Speculum Astronomicum*, full of astronomical tables and replete with erudition; and also published a work called *Sphaera* (Riccioli, *Almagestum Novum*, I, page XXXIV).

The conjunction of Jupiter and Saturn in the year 1603 was not a *triple* conjunction. In that year there was only one conjunction of Jupiter and Saturn, and that occurred on December 18 in Sagittarius. To be sure, it was a remarkable fact that in the very same constellation a conjunction of Saturn and Mars took place on September 26, and a conjunction of Jupiter and Mars on December 19, and so the three major planets were to be seen simultaneously in the same constellation! Thus, it is true that the three planets came into conjunction, but the phenomenon was quite different from the triple conjunction of Jupiter and Saturn of the year 6 B.C. which was followed by a conjunction of Mars in the next year.

In his conclusion Professor Garrett quotes the following sentences from Dr. Seiss ("The Gospel in the Stars," p. 435): "Kepler, on consulting the periods of the conjunction between Jupiter and Saturn, gave it as his opinion that such conjunctions astronomically coincided with the approach of each climacteric in human affairs: to-wit, the revelation of Adam, the birth of Enoch, the Deluge, the birth of Moses, the birth of Christ, the birth of Charlemagne, and the birth of Luther."

It should be borne in mind that Kepler distinguished between the so-called conjunctiones *magnae* and the conjunctiones *maximae*. In his "Epitome Astronomiae" (Book VI, Part 5, edition Frisch, Vol. VI, p. 495) he puts the question: "What is a conjunctio magna?" He answers: A conjunctio magna is "a conjunction of Saturn and Jupiter which generally lasts long enough for Mars, the third of the major planets, to approach closely the other two planets, thus presenting a very conspicuous spectacle: three bright stars radiating without scintillation from the same spot of the heavens." Kepler then adds: "What is a conjunctio maxima?" Answer: A conjunctio maxima is "a conjunction of Jupiter and Saturn which takes place near the beginning of the zodiac, *viz.*, the first point of Aries." Such a conjunctio maxima (not to be mistaken for a conjunctio triplex!) occurs in round numbers once every 800 years. According to Kepler, the first one occurred at the creation of Adam in the year 4,000 B.C., and the following ones coincided with the ages of Enoch, Noah, Moses, Isaias, Christ our Lord, Charlemagne, Rudolph II. Note that the latter (8th) conjunctio maxima did not signalize the birth of Luther, as Dr. Seiss would have us believe. The eighth conjunctio maxima took place according to Kepler in the year 1583, under the reign of Emperor Rudolph II (1552-1612), exactly one century after the birth of Luther. As to the ninth conjunctio maxima, about the year 2,400 A.D., Kepler says wonderingly: "Where shall we be then and our now most flourishing Germany? If indeed the world itself will then still be in existence. . ."

The Planets in May, 1949

By RAYMOND H. WILSON, JR.

NOTE: The time employed is Central Standard Time unless otherwise indicated. The phenomena have been chosen and described for the North American continent, and especially for the United States. The basic data have been taken principally from the *American Ephemeris and Nautical Almanac*.

Sun. During this month the sun will climb from 15 to 22 degrees north of the equator. Thus the northern hemisphere will be receiving sun light and heat at the midsummer rate.

Moon. The phases of the moon will occur as follows:

First Quarter	May 5	4 P.M.
Full Moon	12	7 A.M.
Last Quarter	19	1 P.M.
New Moon	27	4 P.M.

The moon will be nearest to the earth on May 10.

Evening and Morning Stars. Saturn in Leo will be favorably placed for early evening observation; while Jupiter will be conspicuous in the morning sky.

Mercury. The first half of this month will be a most favorable period for observing this elusive planet in the evening sky. On May 10 it will be 22 degrees east of the sun at a declination nearly 25 degrees north. It may also be seen just after sunset on April 29, less than a degree south of the young moon.

Venus. This brightest planet will be receding eastward from the sun, so that by the end of the month it may be seen up to an hour after sunset. Just after sunset on the 26th and 27th it may be glimpsed just a degree north of Mercury. On the 28th the new moon will join this remarkable group.

Mars. Mars will still be practically unobservable, although by the end of the month it will rise almost an hour ahead of the sun.

Jupiter. By the end of the month Jupiter will be rising before midnight, and it will be south at 4 A.M.

Saturn. At the beginning of the month Saturn will be almost stationary at about a degree northeast of Regulus in the evening sky.

Uranus. Uranus will be moving eastward at a position 4 degrees east-northeast of δ Tauri.

Neptune. Neptune will be moving northwestward at a position about 3 degrees southeast of γ Virginis.

Department of Mathematics, Temple University, Philadelphia, Pa.
March 6, 1949.

Occultation Predictions for May, 1949

(Taken from the *Amerian Ephemeris*)

The quantities in the columns *a* and *b* are given for the purpose of making these predictions useful for any place within 200 miles of the point indicated. The procedure is as follows: Subtract the longitude of the point given from the longitude of the place in question; multiply the result in degrees, taking the signs into account, by the quantity under *a* for the star to be observed; similarly, with the latitude, using *b*; apply the sum of the products, with its proper sign, to the Greenwich C.T., and obtain the predicted Greenwich Civil Time for the phenomenon at the place of observation. To obtain Eastern Standard Time it is necessary to subtract five hours; Central Standard Time, six hours, etc.

			IMMERSION				EMERSION			
Date 1949	Star	Mag.	Greenwich C.T.	*a*	*b*	Angle E from N	Greenwich C.T.	*a*	*b*	Angle E from N
			h m	m	m	°	h m	m	m	°
Occultations Visible in Longitude +72° 30′, Latitude +42° 30′										
May 5	28 Canc	6.1	0 17.1	—2.0	—0.4	79	1 15.3	—0.2	—2.8	332
8	308 B.Leon	5.9	0 20.5	—1.3	—1.1	131	1 34.8	—1.4	—1.3	306
16	183 B.Sgtr	6.2	6 6.9	—1.5	+0.8	98	7 27.9	—2.0	+0.6	257
19	154 B.Capr	6.1	7 53.8	—1.3	+2.3	28	9 0.3	—2.2	+0.8	281
31	134 B.Gemi	6.5	1 12.2	+0.1	—1.6	113	2 5.8	+0.2	—1.2	276
Occultations Visible in Longitude +91° 0′, Latitude +40° 0′										
May 4	28 Canc	6.1	23 43.3	—1.9	—1.0	113	1 4.5	—1.5	—1.5	294
5	ν^1 Canc	5.7	1 35.3	—3.0	+1.1	58	2 14.5	+0.6	—4.1	354
8	308 B.Leon	5.9	0 5.7	—0.6	—2.4	168	1 1.5	—2.4	+0.9	265
9	13 Virg	5.9	7 41.7	—0.6	—1.5	97	8 35.3	—0.2	—2.0	325
15	CD—28°14268	6.4	9 14.0	—1.9	+1.0	39	10 8.8	—2.4	—1.8	317
19	154 B.Capr	6.1	7 26.2	—0.9	+2.4	36	8 27.0	—1.1	+1.1	284
31	134 B.Gemi	6.5	1 20.2	+0.3	—2.5	146	2 6.4	—0.6	—0.7	247
Occultations Visible in Longitude +98° 0′, Latitude +31° 0′										
May 2	107 B.Auri	6.5	2 28.5	—0.9	—0.1	61	3 19.2	+0.5	—2.0	309
3	49 Auri	5.0	2 41.6	—1.3	—0.2	67	3 33.0	+0.4	—2.3	319
4	28 Canc	6.1	23 48.6	—1.5	—3.3	154	0 55.4	—3.0	+0.6	254
5	ν^1 Canc	5.7	1 20.9	—2.1	—1.1	104	2 37.9	—0.9	—2.1	311
5	ν^2 Canc	6.4	2 22.8	—3.3	+1.0	61	3 3.1	+0.8	—4.1	0
9	13 Virg	5.9	7 50.5	—0.7	—1.6	116	8 50.3	—0.3	—1.7	308
15	CD—28°14268	6.4	8 48.6	—2.6	+1.0	59	10 5.2	—2.6	—1.3	302
22	4 Ceti	6.3	9 39.1	—0.6	+1.2	89	10 38.7	—0.6	+2.6	207
22	5 Ceti	6.3	9 58.2	—0.7	+1.4	82	11 3.2	—0.8	+2.5	211
Occultations Visible in Longitude +120° 0′, Latitude +36° 0′										
May 4	ν Gemi	4.2	2 54.0	..	..	38	3 17.8	..	..	0
5	ν^2 Canc	6.4	1 23.8	—2.5	+0.3	86	2 38.5	—1.2	—2.5	321
9	13 Virg	5.9	7 20.2	—1.1	—1.8	134	8 28.3	—1.0	—1.7	300
9	η Virg	4.0	8 2.4	—2.7	+0.2	61	8 30.8	+0.5	—3.6	11
15	CD—28°14268	6.4	8 2.3	—1.9	+1.4	72	9 13.3	—1.6	—0.3	306

METEORS AND METEORITES

Contributions of The Meteoritical Society

(Known Formerly as The Society for Research on Meteorites)

Edited by FREDERICK C. LEONARD
Department of Astronomy, University of California, Los Angeles 24

A Composite Spectrum of a Perseid Meteor of 1948*

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ABSTRACT

A spectrum of a Perseid meteor, observed on 1948 August 11, from a place near Blairsden, Plumas County, California, is discussed. This spectrum exhibits, along successive segments of the visible path of the meteor, the characteristics of all 3 spectral types, *Z*, *X*, *Y*, in that order. These variations in the spectrum of a single meteor substantiate the hypothesis that differences in meteor spectra result from changes in the excitation of the meteoritic vapor, rather than from differences in the composition of the meteorites themselves.

The classification of meteor spectra into types *X*, *Y*, and *Z* was first proposed by Dr. Peter M. Millman.[1] His survey of the 24 meteor spectra photographed prior to 1935 indicated that they divided themselves naturally into 2 classes, which he termed *Y* and *Z*. In type *Y*, the H and K lines of ionized calcium are the most prominent features, whereas, in type *Z*, ionized calcium is absent, and almost all the lines are due to iron. The only spectrum of the 24 that did not fall definitely into class *Y* or class *Z* was that of a Perseid, in which the H and K lines, tho clearly visible, were surpassed in brilliance by a line at wavelength about 3835 A. (A. = angstrom units), a blend of magnesium and iron. With commendable conservatism, Millman stated that, in view of the scanty observational material available, it seemed unwise to propose a more extended system of classification at that time. In the event that more spectra of this lone type were found, however, he suggested that they might be referred to as belonging to type *X*. The nearly stationary meteor discussed in this paper exhibited spectral characteristics of types *X*, *Y*, and *Z* at different heights along its path, which was approximately only 2½° in length.

The spectrum was photographed on Eastman "Super XX" film in a kodak with an *f*/5.6 lens of 130 mm. focal length, in front of which was mounted a 30° dense-flint prism. This arrangement gave an average dispersion between Hδ and Hγ of 468 A./mm. The photograph reproduced in Fig. 1 was obtained at a place approximately 5 miles west of Blairsden, Plumas County, California, at an altitude of 5000 feet above sea-level, on 1948 August 11, at $22^h 08^m$ P.S.T. The spectrum is shown between and below the spectra of the stars ε and δ Cassiopeiae.

The hydrogen lines in the spectrum of δ Cassiopeiae (spectral cl. = A5) were

*A preliminary report on this spectrum was given at the 11th Meeting of the Society, Albuquerque, New Mexico, 1948 September 7-8.

FIGURE 1
THE SPECTRUM OF A PERSEID METEOR OBSERVED ON 1948 AUGUST 11, ASCENDING TOWARD ϵ AND δ CASSIOPEIAE

measured from Hα to Hζ, and 2 Hartmann formulae were computed, one using Hα, Hγ, and Hζ, and the other, Hγ, Hδ, and Hζ. The latter formula reproduced the wavelength of Hϵ within 0.08 A., and was employed for the determination of all wavelengths in the meteor spectrum shorter than 4500 A. The Hartmann formula based on the greater wavelength-range was used to strengthen the determination of wavelength for 3 lines in the meteor spectrum to the red of 5000 A. Hβ was not used in these formulae, because it fell in a region of decreased plate sensitivity, and was difficult to measure. The positions of 21 lines in the meteor spectrum were measured at the time of the second burst. These readings were converted to the scale of the hydrogen lines in the spectrum of δ Cassiopeiae by assuming that the 2 strongest lines in the meteor spectrum during the bursts were the H and K lines of calcium. This assumption is justified by the fact that, in nearly all spectra of shower meteors, the H and K lines predominate. If this assumption is made, all the other lines in the meteor spectrum are satisfactorily identified with elements that are common in meteorites and that have easily-produced spectral lines in the region covered by the meteor spectrum.

The results of the spectral reduction are shown in Table 1. Column 1 gives the observed wavelengths for the lines in the spectrum of the meteor, and column 2, a rough visual estimate of the intensity of the lines on a scale of 10, intensity 10 corresponding to the intensity of the strongest line, and intensity ½ to the intensity of a line just above the limit of visibility. In columns 3 to 10 are listed the wavelengths and intensities of the multiplet lines that comprise the spectral lines of the meteor. These data and the number used to designate each multiplet were taken from the Revised Edition of Dr. Charlotte E. Moore's "Multiplet

TABLE 1

IDENTIFICATION OF THE LINES IN THE SPECTRUM OF THE METEOR

Observed Wavelength	Intensity	Multiplets								Computed Wavelength	Intensity	O-C Angstroms
		Fe I (5)		**Fe I (21)**								
3722.5	½	3720_{250}	3723_{50}	3728_{50}						3721.6	½	0.9
3737.3	3	3733_{40}	3737_{150}	3735_{200}						3735.4	2½	1.9
3751.5	3½	3746_{100} 3748_{60}	3746_{40}	3743_{20}	3749_{200}					3747.6	4	3.9
3761.2	3			3758_{150} 3767_{80}	3764_{100}					3762.0	3	— 0.8
3797.9	½			3788_{50} 3799_{40}	3795_{60} 3800_{50}					3795.3	1	2.6
		Fe I (4)		**Fe I (20)**		**Fe I (45)**		**Mg I (3)**				
3819.6* }	6	3824_{50}		3820_{250}	3826_{200}	3816_{100}				3821.5 }	6	— 1.9
3838.9 }				3834_{100} 3850_{40}	3840_{80}	3828_{75}	3841_{80}	3829_{40} 3838_{100}	3832_{80}	3836.1 }		2.8
3861.1	5	3856_{50}	3860_{300}	3866_{30}	3873_{80}					3861.7	4	— 0.6
3884.9	1	3879_{100} 3896_{25}	3886_{40}	3878_{60}	3887_{15}	3889_{20}				3882.5	1	2.4
3910.4	½	3900_{30}	3906_{8}	3898_{10}	3917_{8}	3903_{20}				3903.4	½	7.0
								Ca II (1)				
3934.6	10	3920_{20} 3928_{30}	3923_{25} 3930_{25}	3941_{5}				3934_{400}		3932.6	5	2.0
				Fe I (43)								
3967.7	9			3969_{20}		3966_{10}		3968_{350}		3968.0	4	— 0.3
4060.7	½			4005_{25} 4064_{45}	4046_{60} 4072_{40}					4051.9	½	8.8
		Fe I (3)				**Fe I (42)**						
4130.1	1	4134_{1}	4150_{1}	4132_{25}	4144_{20}	4148_{10}				4140.0	½	— 9.9

NOTE TO TABLE 1

*3819.6 is the sharp edge of a broad line.

TABLE 1 (CONT.)

Observed Wavelength	Intensity	Multiplets								Computed Wavelength	Intensity	O-C Angstroms
							Fe I (152)					
4215.5	1½	4200_{1} 4216_{8}	4207_{3}		4202_{20}	4251_{25}	4187_{20} 4191_{15} 4210_{15} 4234_{18} 4250_{5}	4188_{20} 4198_{20} 4222_{12} 4236_{25}		4216.7	1	— 1.2
				Fe I (41)								
4283.6	½	4258_{2}	4291_{4}	4294_{15}		4272_{5}	4308_{25}	4260_{25} 4299_{18}	4271_{20}	4282.5	1	1.1
		Fe I (2)										
4362.4	1	4326 4376_{0} 4405	4347_{1} 4389_{2}	4337_{10} 4405_{30}	4384_{45} 4415_{20}	4326_{5}				4375.5	1	—13.1
				Fe I (350)								
4469.6	2	4427_{10} 4445_{1} 4467 4482_{4}	4435_{3} 4462_{8} 4472_{1} 4490_{3}	4467_{12}	4476_{10}					4461.1	½	8.5
		Fe I (1)		Fe I (15)		Fe I (36)		Fe I (37)	Mg I (2)			
5245	2	5060_{1} 5128 5169_{4} 5205_{2} 5226_{1} 5250_{1}	5110_{10} 5166_{4} 5176 5221 5247_{1} 5255_{1}	5270_{60} 5371_{50} 5406_{40} 5435_{20} 5456_{40} 5501_{12}	5328_{50} 5397_{40} 5430_{40} 5447_{40} 5498_{15} 5507_{18}	5042_{10} 5195_{10}	5172_{20} 5216_{10}	5167_{40} 5227_{40} 5270_{30} 5329_{15} 5341_{20}	5167_{40} 5173_{80} 5184_{125}	5290	3	—45
		Fe I (62)	Fe I (111)	Fe I (168)		Fe I (268)		Fe I (816)				
6492	4	6335_{10} 6431_{200}	6421_{200} 6663_{80}	6318_{10} 6463_{20} 6594_{80}	6394_{400} 6495_{1000}	6546_{200} 6678_{600}	6593_{200} 6704_{10}	6246_{25} 6337_{12} 6408_{60}	6302_{15} 6400_{800} 6412_{400}	6488	4½	4
								Fe I (1051)				
7105	1		6750_{100} 6945_{150} 6979_{100}			6807_{10}		7000_{20} 7023_{50} 7090_{40} 7164_{250} 7207_{500}	7016_{80} 7038_{40} 7131_{150} 7187_{500}	7124	1	—19

Table of Astrophysical Interest."[2] Lines of intensity less than 10, and lines for which no intensities were available, were omitted, except iron lines produced by transitions to the 2 lowest energy-levels. Individual multiplets have been assigned a separate column or columns. The next 2 columns (nos. 11 & 12) contain computed wavelengths and intensities for the meteor lines, based on the wavelengths and intensities of the constituent multiplet lines. In comparing the observed and the computed wavelengths, it is to be remembered that the computed wavelengths are means of numerous values weighted in a somewhat arbitrary fashion. The computed intensities are crude, and are intended to supply only a rough substantiation of the line identification. In calculating the intensities, an allowance was made for the decrease in plate sensitivity at both ends of the spectrum, by reading corrections from a smoothed curve.

In consideration of the uncertainties involved in the computed wavelengths, the agreement between observation and calculation seems tolerable. For all but the last 3 lines, the average residual is 3.9 A. The size of the last 3 residuals may be attributed in part to the broadness of the lines and to the very low dispersion, which, between Hα and Hβ, averages 1812 A./mm. The line at 7105 A. lies outside the wavelength-limits of the lines used for computing the Hartmann formula; so the correction for this line had to be extrapolated. There are 2 other factors involved in the residual of —45 A., for observed wavelength 5245 A. First, this residual would be reduced by giving additional weight to the iron lines of multiplet No. 1, for which the excitation potentials are the lowest of any iron multiplet. Millman[3] gave added weights, ranging from 2 to 6, to iron multiplets arising from the lowest level. Second, the long-wavelength edge of this line dips into the region of decreased plate sensitivity, thus tending to make the observed wavelength too short.

Perhaps the most striking feature of Fig. 1 is the stratification of the spectrum into 3 layers. The lowest third, which was the first one to be impressed upon the plate, shows no sign of the H and K lines. The faint lines that do appear could be attributed entirely to iron. Had this first third of the spectrum been the only part observed, the spectrum would have been classified as one of type *Z*. In the middle third of the spectrum, the H and K lines are prominent, but not so strong as the iron-magnesium line at 3839 A. This section of the spectrum is typical of class *X*, the only previously published example of which, to the best of my knowledge, has already been mentioned.[1] The third, last, and most brilliant layer of the spectrum is characterized by the lines of ionized calcium, which are very strong, particularly in the 5 rather evenly-spaced bursts. The chronology of these spectral changes seems unaccountably at variance with the results of Millman's studies.[1] On the basis of the measured heights of 8 meteors, Millman found that those seen above 80 km. were of type *Y*, whereas those seen below 80 km. were of type *Z*. The meteor under discussion, however, appeared first as a meteor of type *Z*, and disappeared as a meteor of type *Y*. Altho no photometric study of the spectrum has as yet been made, there is scarcely room for doubt that the strength of the H and K lines increased relatively to that of the iron-magnesium line at 3839 A. as the meteorite penetrated farther into the atmosphere. As the line 3839 A. is produced by neutral atoms with excitation potentials well below the ionization potential of calcium, the sequence of spectral changes indicates increasing excitation as the meteorite moved earthward. These changes do, however, strongly substantiate Millman's hypothesis,[1] that differences between types of spectra originate probably in differences in the degree or kind of excitation of the meteoritic vapor, rather than

in differences in the composition of the meteorites themselves. It appears further that these changes take place rather suddenly, as tho the meteorite passes from one homogeneous atmospheric layer into another, in which different physical and/or chemical conditions prevail. The changes that take place at the boundaries of these postulated layers are more marked than any changes that occur during the penetration of the layers by the meteorite. It is to be regretted that this meteor was not simultaneously observed from another point, so that the heights and lengths of the several path-segments could be ascertained.

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[1] Millman, Peter M., "An Analysis of Meteor Spectra: Second Paper," *Harvard Coll. Obs. Ann.*, **82**, No. 7, 149-77, 1935.

[2] *Princeton Obs. Contr.*, No. 20, 1945.

[3] Millman, Peter M., "An Analysis of Meteor Spectra," *Harvard Coll. Obs. Ann.*, **82**, No. 6, 113-46, 1932.

President of the Society: ARTHUR S. KING, 925 Topeka Street, Pasadena 6, California

Secretary of the Society: OSCAR E. MONNIG, 1010 Morningside Drive, Fort Worth 3, Texas

Comet Notes

By G. VAN BIESBROECK

No new comets have been announced so far this year. Those of last year, that are still under observation, are all faint and losing in brightness. In the following table they are listed in order of right ascension and the rough brightness at the last known date is indicated. Not listed are the comets that can only be observed in the southern hemisphere.

Comet	Date	Magnitude	Remarks
1948 *i* Ashbrook-Jackson	Feb. 18	16	Low altitude
1948 *d* Pajdusakova & al.	Feb. 16	14	
1948 *m* Bester	Feb. 18	15	
Periodic Oterma	Feb. 19	17	
Periodic Whipple	Jan. 18	16	
1948 *l*	Feb. 16	11	
Periodic Schwassmann-Wachmann No. 1	Feb. 17	16	Variable
Periodic Schwassmann-Wachmann No. 2	Feb. 28	16	

The expected periodic Comet Gale (1927 VI) which has been seen at its 1938 return is due again at perihelion in April but it has not been found so far. Exposures made here with the 24-inch reflector showing stars down to 16th magnitude in the region predicted by Dinwoodie (see p. 141) have not shown the presence of the comet. While I visited the Goethe Link Observatory on March 7, Dr. F. Edmondson took at my request a pair of plates there with the 10-inch Cooke lens. The plates were guided for the motion of the comet and should have revealed its presence even if it had been as faint as 16th magnitude. The field covered $\pm 3°$ in right ascension and $\pm 4°$ in declination. Yet the search proved futile. Either the object is very much fainter than expected (13^m6 on March 7) or else the prediction is not accurate enough. The predicted maximum of brightness is 12^m3 for the middle of April. The search is being continued.

Williams Bay, Wisconsin, 1949 March 13.

Communications and Comments

Under this heading we shall publish from time to time such material as does not properly fall under any of the established headings of this journal. Here, too, may be found, when occasion arises, articles which the editor may not be willing to give sanction to but which, nevertheless, may be provocative of thought along new lines.

A Photo-multiplier Telescope

Did you ever hear of a photo-multiplier telescope? It is the invention of William A. Rhodes of Phoenix, Arizona, who has been working on the idea for about three years. He did all the construction work, which is quite a feat considering that the completed telescope weighs 1500 lbs.; it houses a 12-inch f.8 reflector.

The telescope is complicated but can be explained in laymen's terms. It works by bringing light from the distant objects into an ordinary telescope with a glass reflector, but instead of going into an eyepiece where only one person at a time may view the scene it is caught by a special cell, broken up into electrical impulses and sent by wire through an amplifier.

In the amplifier its strength is built up to many times the original. The impulses are then sent through a tube, similar to a cathode ray tube where they are converted back into an image. This image is picked up by still another lens and thrown upon the screen of a special photo-multiplier invented by Mr. Rhodes. When the image emerges on the other side of this window, it has been built up to blinding brilliance. This photo-multiplier, is the key to the success of the instrument, and is a radical departure from any existing unit. So radical in fact that it could easily be adapted to television and countless other applications where economical and true reproduction is essential. This unit is about four inches in diameter and about an eighth of an inch in thickness, takes little equipment to make it operate, is very stable and can take an extremely weak image and increases its brilliance thousands of times if necessary. The resultant image is the same size as the image that strikes the back of the multiplier. An ordinary projector lens then picks it up and casts the final image upon an 8-inch screen where it may be viewed directly by a group of people.

The lunar landscape comes through with such clarity that it appears as though it were actually protruding up out of the glass screen like a plaster relief map, and anything on the moon a mile across is clearly visible. Naturally the definition of the image can be no better than that which our atmosphere permits.

The amplification may be turned up so that a cross-section of 280 miles of the moon may be viewed by one-hundred people simultaneously, and with extreme clarity. The instrument should not be compared to any existing glass telescope. The inventor states that while it could produce an image of the moon many times larger and brighter than the giant 200-inch Palomar telescope can, and probably a sharper image because of the small entrance beam, its sensitivity decreases so rapidly with distance that the planet Saturn is about the limit of its useful range. Stars of the first and some second magnitude come through as bright spots on the screen, but the internal radiation of the pickup cell, called dark current, puts a definite barrier to weaker objects. The inventor is hopeful that further research will improve this condition. This is not too much of a draw-back however, as this same amplifier system may be used on much fainter objects as the size of the primary mirror is increased. The photo-multiplier tele-

scope is primarily an instrument designed to bring the heavens into view of many persons at once rather than an attempt to improve upon the standard existing telescopes. The limiting factor is not the telescope but the turbulence of our atmosphere. The fine telescopes that exist in this country and in other parts of the world could increase their usefulness tremendously if the atmosphere were suddenly to cease trembling.

It is believed that this instrument is the first of its kind ever to permit whole groups to view a heavenly body at one time.

William A. Rhodes, Inventor.
Phoenix, Arizona, 1227½ E. Van Buren St.

Planetary Evolution: A New Hypothesis

Since 1796, when the great philosopher-scientist, Laplace, proposed his celebrated "Nebular Hypothesis," astronomers of all countries have vied one with another in the attempt to explain the origin of our planetary system. Laplace's hypothesis has been outmoded for fifty years at least; and while a dozen or more astronomers in Europe and America have proposed counter theories, to date all of them have failed of universal recognition largely because of failure to account for the enormous angular momentum of Jupiter. Convinced that no hypothesis can explain the origin and evolution of our planetary system unless it does account for this tremendous angular momentum, which exceeds the combined angular momenta of the other planets and the sun, the present writer offers a new hypothesis based largely on this scientific fact.

All previous theories have assumed that our nine known planets once were a part of the sun's mass. However, as the angular momentum of the sun is only about 3% of the total angular momentum of the solar system, it appears incredible that the sun could have spawned planets—even one planet—with vastly greater angular momenta. Astronomers inform us that the sun contains more than 99% of the mass of the solar system; yet its angular momentum is only about 3% whereas that of Jupiter—according to Moulton—is nearly 60%. Jupiter's mass is greater than the combined mass of the other planets, and though it is immensely smaller than the sun—its diameter being 86,700 miles as against 864,390 miles for the sun—its angular momentum is approximately twenty-two times as great. If at some time in the far distant past Jupiter was a part of the sun, and by some means was expelled, or, perhaps, pulled out by the gravitational attraction of a passing star, it appears utterly impossible to explain how the parent sun could have communicated to Jupiter an angular momentum so much greater than its own. The discrepancy dissolves into dire confusion when we take into account the respective angular momenta of Saturn, Uranus, and Neptune, each of which has an angular momentum very much greater than that of the sun.

Assuming that the total angular momentum of the four major planets—Jupiter in particular—is the key to any solution of planetary formation, the hypothesis herewith proposed alleges that two or more billions of years ago Jupiter was a companion star to our sun, incorporating in its mass the total mass of the other eight known planets. Among astronomers it is a truism that approximately one star in every three is a member of a binary, or multiple, system, therefore the present hypothesis is justified in assuming that our sun may have had a companion star, and that this companion was Jupiter. It is well known that in many of these binary, or multiple, systems one member often is much smaller than its companion.

Astrophysical experts like Russell, Shapley, Jeans, Eddington, Jones, *et al.*, believe that, while collisions between stars are very infrequent, they have occurred. Backed by this belief the hypothesis proposed herewith assumes that some billions of years ago a wandering star, somewhat larger than our sun, ventured perilously near our binary system. When it reached a critical distance—which of course can not be computed since we do not know the respective masses of the two large suns—a gigantic tug of war began between it and our sun, so Jupiter was forced to play the role of buffer. As the gravitational pull of the wanderer was greater than that of our sun it raised on Jupiter huge tidal masses, larger on the side next to it than on the side next to the sun. When this mad wanderer in its parabolic or hyperbolic orbit came nearest to Jupiter the huge tidal filaments were snatched from the Jupiter mass. Necessarily these varied, those on the side nearest to the wanderer being larger than those on the opposite side. If the wanderer had ventured much closer to Jupiter, or had been very much larger, it would have carried with it as it swept majestically through space most, if not all, of these tidal filaments; or possible might have caused a total disintegration of the Jupiter mass.

When the wanderer rushed from the scene of its cosmic filching, unable to carry along the disorganized tidal masses, the sun proceeded to take charge of the messy situation. Whatever vaporous masses—if any—had been pulled from the sun were in time retrieved. The tidal masses snatched from Jupiter thereby reducing its mass of approximately one half and proportionately lessening its gravitational attraction, instead of falling back into Jupiter responded to the now-much-stronger pull of the sun; and as they revolved about the sun their disorganized masses slowly condensed until in the course of time they formed the planets and were orbitally regimented. Whatever its former distance from the sun, Jupiter must have yielded to the powerful attraction of the wanderer, and when the latter had disappeared, never to return, Jupiter must have been many millions of miles farther away from its former companion, doomed thenceforth to forfeit its once-proud stellar status and assume the humble role of planet.

The hypothesis accounts for the relatively small masses of Mercury, Venus, the Earth, and Mars, and the very much larger masses of Saturn, Uranus, and Neptune by respective differences in the gravitational pull of the wanderer on the two sides of Jupiter. Necessarily the tidal filaments that ultimately condensed into Saturn, Uranus, and Neptune were filched from Jupiter at brief intervals when the wanderer was nearest. Taking into consideration the respective distances from Jupiter of these planets, and their individual masses, the angular momentum of each of these major planets is what might be expected. Neptune, remotest of the three, has an angular momentum only one-seventh or one-eighth that of Jupiter, while Saturn, nearest of the three, has an angular momentum somewhat more than three times that of Neptune, and only approximately one-half that of Jupiter. The vastly smaller angular momenta of Mercury, Venus, the Earth, and Mars are readily accounted for on the score of their nearness to the sun, which gradually slowed down their periods of rotation.

Contributory evidence in support of the hypothesis may be found in the respective planetary densities. According to Duncan of Wellesley the mean density of the sun as compared with that of water is 1.4 while the mean density of Jupiter is 1.3. This similarity of mean density between Jupiter and the sun certainly justifies no one in saying that Jupiter never could have been a sun. Further, the well-authenticated data showing that the mean density of each of the three outer large planets, Saturn, Uranus, and Neptune, is small in com-

parison with the much larger mean densities of Mercury, Venus, the Earth, and Mars, give added weight to the hypothesis.

With due modesty the writer offers this tentative hypothesis of planetary formation fully conscious that he is walking in the shadow of astronomical experts.

LABAN LACY RICE.

Ware Neck, Virginia.

Memoranda on Meteoritics

The material herein, presented briefly and in a suggestive sense, is submitted as of possible interest to students of meteoritics. A very remarkable phenomenon of some fireballs is that of a spiral or corkscrew train which would seem to indicate that the meteor body itself described a spiral path in the atmosphere.[1] In "Life" magazine for June 7, 1948, is a record of U. S. Naval research on torpedoes illustrated by photographs of the spiral wakes of spinning steel balls in water. The dynamics of this research applied to fireballs would explain the corkscrew trains. It would seem more logical to believe that the meteor body itself does not follow a spiral path. This has no doubt already occurred to meteoriticists.

A second note of interest is the publication of a book entitled "Yale Science" by Louis McKeehan commemorating the first hundred years of science at Yale. In it are interesting accounts of very early work on fireballs especially by a Professor Clap who it would seem is a forgotten man of meteoritics. In the 1750's he had already done more work on fireballs than anyone else had done fifty years later. It also adds another name to a list of men who worked on meteors in New Haven which includes Newton, Olmstead, Herrick, Shepard, Elkin, Twining, and, lesser knowns, Palmer, Lyman, and Mason.

A third memorandum is that on possible interference to television programs by meteors. The phenomenon of signal "bursts" due to meteors is especially noticeable on FM stations in the neighborhood of television frequencies.[2] Under certain conditions depending mostly on the television station's distance, such interference should manifest itself in doubling of the image and intermittent reception. The importance of such an experiment besides the mere "for the record" value is that it should lead to new methods, techniques, and indication instruments in studying meteors which would improve on radar. Using the phenomenon of signal bursts and Doppler whistles, a special transmitter with a suitable wave length and type of wave, operating at an appropriate distance and broadcasting an image of a line or pattern of lines on an optical path and also to a sky area toward a receiver, should show a doubling and motion of the lines.

It may then be possible to plot accurately the path of the meteor from the television indicator, discover the height, speed, and radiant of each meteor and follow the direction of drift of the "radio" train which lasts much longer than the visual appearance. Some thought on this by radio astronomers will show that such results are not as amazing as they seem at first reading of this note and will in fact indicate still other possibilities which are beyond the intent of the writer to discuss at this time.

VINCENT ANYZESKI.

1575 High Street, East Haven, Conn.

REFERENCES

[1] Long Enduring Meteor Trains. Papers 1 and 2. C. P. Olivier.
[2] QST Jan. 1946 and July 1947. O. G. Villard.

A Mathematical Formulation of Bode's Law

In all textbooks of astronomy, in which the law of Johann Elert Bode is mentioned, it is given in this way.

If the number 4 will be added to each of the numbers 0, 3, 6, 12, 24, 48, 96, and 192 and these are divided by 10, the resulting series represents, approximately, the distances of the planets in astronomical units from the Sun, thus 0.4 Mercury, 0.7 Venus, 1 Earth, 1.6 Mars, 2.8 Asteroids, 5.2 Jupiter, 10.0 Saturn, 19.2 Uranus, 38.8 Neptune, 77.2 Pluto.

		Distance (Computed)	Distance (Bode'sLaw)
1.	Mercury	0.39	0.4
2.	Venus	0.72	0.7
3.	Earth	1.00	1.0
4.	Mars	1.52	1.6
5.	Asteroids	2.77	2.8
6.	Jupiter	5.20	5.2
7.	Saturn	9.54	10.0
8.	Uranus	19.19	19.6
9.	Neptune	30.07	38.8
10.	Pluto	39.52	77.2

As seen from this table Bode's Law is approximately correct for the eight planets, which are nearest to the Sun. We must consider that these distances are only the mean distances as the orbits of the planets are not exactly circular.

For the first 8 planets, expressing Bode's law in the formula,

$$d_n = 0.4 + 0.3\ (2^{n-2})$$

astronomical units, we have after the first,

		Distance (Computed)
$n = 1$	$d_1 = 0.4 + 0 = 0.4$	0.39
$n = 2$	$d_2 = 0.4 + 0.3 \times 1 = 0.7$	0.72
$n = 3$	$d_3 = 0.4 + 0.3 \times 2 = 1.0$	1.00
$n = 4$	$d_4 = 0.4 + 0.3 \times 4 = 1.6$	1.52
$n = 5$	$d_5 = 0.4 + 0.3 \times 8 = 2.8$	2.77
$n = 6$	$d_6 = 0.4 + 0.3 \times 16 = 5.2$	5.20
$n = 7$	$d_7 = 0.4 + 0.3 \times 32 = 10.0$	9.54
$n = 8$	$d_8 = 0.4 + 0.3 \times 64 = 19.6$	19.19

For the two outmost planets, Neptune and Pluto, we have to correct this formula, as follows, $n > 7$:

$$d_n = 0.4 + 0.3\ (2^{n-2}) - [(n-8)3]^2.$$

For the first seven planets the last term of this formula has no application. For $n = 8$, its value is 0.

$$n = 9 \qquad d_9 = 0.4 + 0.3 \times 128 - (1 \times 3)^2 = 29.8$$
$$n = 10 \qquad d_{10} = 0.4 + 0.3 \times 256 - (2 \times 3)^2 = 41.2$$

The distances from the Sun for these two cases in astronomical units are:

		Bode	Computed	New Formula
9.	Neptune	38.8	30.07	29.8
10.	Pluto	77.2	39.52	41.2

The new formula gives very nearly the distances of these planets from the Sun, as we have to consider that these are only mean distances.

The author expresses his thanks to Dr. Z. Chajot, Jerusalem, for his valuable help.

S. B. Ullman.

Jerusalem, 16 September 1948.

General Notes

The Rittenhouse Astronomical Society, of Philadelphia, held a joint meeting with the Franklin Institute at the Franklin Institute on Wednesday, March 2. At this meeting Dr. G. Van Biesbroeck of the Yerkes Observatory spoke on the topic "Comets."

Astronomical Research in Germany

That astronomical investigations are in progress in Germany is clearly indicated by the important publications which are received from there. We mention three at this time, all issued by Academie-Verlag GmbH, Berlin.

1. Contribution from the German Academy of Sciences, Berlin, a paper by Dr. Paul Guthnick, "On some unusual newly discovered Eclipsing Variables."

2. Supplement to Astronomische Nachrichten, Volume 11, No. 4, a paper by M. Beyer, "On the Light Change in Variables with Periods from 30 to 150 Days."

3. Supplement to Astronomische Nachrichten, Volume 11, No. 5, a paper by A. A. Wachmann, "Observations of Variables near the Kapteyn Fields of the Northern Milky Way."

These are octavo in size and consist of 18, 113, and 48 pages, respectively.

Regional Convention of Amateur Astronomers

The second regional convention of the Northeast Region of the Astronomical League is scheduled to be held on Saturday and Sunday, April 23-24, at the American Museum of Natural History, New York City, on the invitation of The Bergen County Astronomical Society and The Junior Astronomy Club. Features of the convention will be an address of welcome by Mr. Gordon A. Atwater, Curator, Hayden Planetarium, on "The Role of the Planetarium in Astronomical Education," an address by Dr. Bart J. Bok on "The Center of the Milky Way Galaxy," and field trips to nearby points of astronomical interest, such as Rutherford Observatory, Columbia University, Bergen County Astronomical Society Observatory, Fordham University Seismograph Station, and Watson Computing Laboratory, International Business Machines Corporation.

Advance registration is requested. Write to Mrs. Arthur I. Lee, 244 West 74th St., New York 23, N. Y., for further details.

Provisional Relative Sunspot Numbers*

1	127	11	186	21	168
2	146	12	200	22	133
3	179	13	222	23	135
4	199	14	212	24	148
5	206	15	221	25	143
6	218	16	228	26	126
7	220	17	218	27	140
8	193	18	225	28	152
9	190	19	220	29	
10	176	20	201	30	
				31	

Mean for February
R = 183.3

*From the Zürich Observatory, furnished by Mr. Neal J. Heines.

Astronomers Needed

The Civil Service Commission has informed us that applications are still being accepted for astronomer positions in Washington, D. C., and vicinity. The salaries range from $3,727 to $7,432 a year.

To qualify, applicants must (a) have completed a full 4-year college course leading to a bachelor's degree in astronomy, or (b) have had 4 years of successful and progressive technical experience in the field of astronomy, or (c) have had any time-equivalent combination of (a) and (b). In addition to meeting these prerequisite requirements, applicants must have had from 1 to 4 years of progressive professional experience in astronomy. Graduate study in astronomy may be substituted for as much as 2 years of professional experience. No written test is required.

Full information and application forms may be secured from most first- and second-class post offices, from civil-service regional offices, or direct from the U. S. Civil Service Commission, Washington 25, D. C. Applications will be accepted in the Commission's Washington office until further notice.

Book Reviews

An Introduction to Pakistan

Professor Maneck B. Pithawalla is a noted student of geography and geology, particularly the geography of Pakistan. As the geography of this country is too little known to Americans, Professor Pithawalla's little book should be a welcome addition to the library of any serious student of geography or economics.

After a brief introduction, the author gives first a detailed description of Pakistan including a brief but comprehensive account of the rivers and mountain systems of the country. He then describes the mineral resources of the land, giving much information that is available only in certain technical publications such as those of the Indian Geological Survey. He then goes into a detailed description of the agriculture of Pakistan, giving the crops and their yield and methods of cultivation.

He devotes a separate table and section to the hinterland of Karachi which has a climate different from that of the other parts of Pakistan. There are sections devoted to forests and their value, and to the wild animals of the country.

The following parts of the book are then taken up with communications and with the industrialization of Pakistan, both present and future. The book closes with an account of the population of Pakistan, the problems presented by supporting that population from the resources of the land.

Not the least recommendation of this book is Dr. Pithawalla's clear, easily-read style. This book can be recommended to any person interested in Asiatic affairs, whether from a scientific or practical point of view.

This book can be obtained most easily by writing to the address:

Prof. Maneck B. Pithawalla, D.Sc., F.G.S.
Katrak Building, Victoria Road,
Karachi 3, Western Pakistan.

NOAH AND ANNA LEE MCLEOD.

Aberdeen, Maryland.

Astronomisch-Geodätisches Jarhbuch für 1949. (Published by G. Braun, Karl-Friedrich-Strasse 14, Karlsruhe a. Rhein.)

The "Astronomisch-Geodätisches Jahrbuch" which has recently appeared is an enlargement of the volume formerly issued annually by the Astronomische Rechen-Institut under the name "Astronomische Jahrbuch." This volume of 456 pages contains essentially the material to be found in *The American Ephemeris and Nautical Almanac* and in the British *Nautical Almanac* and others. In addition, this new volume contains material which is needed in the work of geodesy and large-scale land surveys. Arrangements were made in 1896 and again in 1911 for the interchange among the several volumes of this character of certain material which is common to them all. This arrangement is again in effect, and played a part in the preparation of the volume under review. C.H.G.

Relativity for the Man in the Street, by Laban Lacy Rice. (Cumberland University Press, Lebanon, Tennessee.)

This book of approximately 100 pages was issued late in 1948. The author, dispensing entirely with the use of mathematics, "makes no pretence of telling what Relativity *is* only what it is *about.*" The circumstances which led to the development of the body of doctrine now given the name of Relativity are mentioned and discussed. The text is replete with illustrations which bring the discussion down to the level of the technically untrained reader. Both the special, or restricted, theory and the general, or gravitational, theory are touched upon. A few pages of definitions of terms used tend to a clarification of the ideas presented.

Having read this book carefully, one will have acquired at least a little insight into this rather new and frequently mentioned aspect of modern science. It is highly worthy of being recommended to the beginner in this field of study.

C.H.G.

Astronomy for Beginners, by Martin Davidson. (C. A. Watts and Co. Ltd. Fleet Street, London, E.C.4. 2s6d.)

This pocket-sized volume of 150 pages, published in 1948, is number 128 of the series known as the "Thinker's Library." The author, well known in astronomical circles, can be depended upon to produce an authentic treatise. In this case and for the purpose intended, he is necessarily restricted to the elements of the science. It is, however, in a sense a second book on the subject, being a sequel to number 95 in the same series and entitled "An Easy Outline of Astronomy," which passed through several impressions in the course of a few years.

The discussion is divided into eight chapters. At the end of each chapter is printed a list of questions bearing on that chapter. Answers to the questions are given or suggested at the end of the volume. It is well illustrated and serves to give the reader a good idea of the material and scope of the science of astronomy.

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Annuaire Astronomique et Météorologique, published under the editorship of Gabrielle Camille Flammarion, at the Flammarion Observatory at Juvisy, France.

The volume just at hand is the eighty-fifth in the series and is for the year 1949. It resembles in some respects the annual almanacs issued by the several

countries, such as *The American Ephemeris and Nautical Almanac* in the United States. In addition to the regular celestial phenomena which can be presented in the form of ephemerides, this handbook includes other astronomical material as well. In fact it is almost a textbook in astronomy. This particular volume opens with a preface prepared many years ago by the founder, Camille Flammarion, who died in 1925, setting forth the purpose of the publication. Its nearly 400 pages include varied astronomical and scientific discussions ranging from stars and nebulae to the making of telescopes. All in all it is a very useful volume to have at hand.

It, of course, is in the French language. C.H.G.

The Atmospheres of the Earth and Planets. Edited by Gerard P. Kuiper, Chicago. (University of Chicago Press, 1949. 366 pp., 91 fig., 16 plates, $7.50.)

Scientific texts are rarely as exhaustive and up to date as this one. The eighteen contributors are specialists in a number of widely diverse fields which have bearing on the subject of planetary atmospheres—from meteorology and rocket research to spectroscopy and the theory of scattering. In the normal course of events their research papers would have been published in five or more different periodicals, there would have been a host of contradictions and inconsistencies among them, and it would have been unlikely that many readers would ever have read the lot of them. As it happened, however, these astronomers, physicists, meteorologists, geologists, spectroscopists, chemists, and bio-chemists met for a symposium on the occasion of the fiftieth anniversary of the Yerkes Observatory in September, 1947. Their papers were modified toward consistency as a result of the symposium itself and in the preparation of this book, which therefore includes a great deal of new, integrated research as well as a thorough review of earlier work, involving over 500 references. Professor Kuiper's introduction serves to integrate further the wide variety of fact and theory into a logical pattern around two broad themes: The problem of the origin of the solar system and the question of life on other planets.

Neither of these themes is made very explicit; as a consequence, it is left up to the reader to form his own conclusions from the well-established evidence. For instance, Harrison Brown (University of Chicago) shows quite conclusively that the earth's atmosphere is of secondary origin, and therefore that most of the gaseous constituents escaped during the formation of the earth, however it took place. Similarly, with respect to the existence of life on other planets, G. P. Kuiper's summary of pertinent data (including results of his recent infrared studies) is undoubtedly the most complete yet published. The absence of chlorophyll bands in the spectrum of the green areas on Mars rules out earth-like green foliage, but not lichens or mosses. However, even these hardy forms of life would have rough going in the absence of a protective ozone layer or seas of water to live in; they would have had to develop protective coats against ultraviolet light. James Franck (University of Chicago) is given the last word on the changing green areas (which have roused speculation concerning plant life on Mars); he points out that the changes in surface color may be simply due to inorganic chemical changes.

The specialist will find "The Atmospheres of the Earth and Planets" exceptionally revealing in that it links his speciality with so many others. For instance, few astronomers are aware of the recent meteorological work on the circulation of the lower atmosphere, which is presented by C. G. Rossby (University of

Chicago), and well illustrated with sample weather charts and vertical sections of the atmosphere. Nor are astronomers generally familiar with the rocket research now going on at White Sands, New Mexico, under Army auspices. The techniques in use, the ultraviolet spectra of the sun obtained at altitudes from 55 to 155 km., and the composition and conditions of the atmosphere measured directly at these great altitudes, are covered in papers by J. L. Greenstein (California Institute of Technology), H. E. Clearman (Applied Physics Laboratory), and E. Durand (Naval Research Laboratory). Again, the probable evolution of the atmosphere from the lithosphere, as conceived by a geologist, is discussed by the late R. T. Chamberlin (University of Chicago).

Among the interesting theoretical papers is a discussion by Lyman Spitzer (Princeton) of the "exosphere," the "spray" of free-moving atoms and molecules at the top of the atmosphere, altitude 600 km. or greater. Other papers, which cannot all be described here, are contributed by H. C. van de Hulst (Yerkes Observatory), F. L. Whipple (Harvard), P. Swings (University of Liege), A. Adel (University of Michigan), M. V. Migeotte (Ohio State), T. Dunham, Jr. (Mt. Wilson Observatory), and G. Herzberg (Yerkes Observatory).

For the professional astronomers, the complete name and subject indexes will make "The Atmospheres of the Earth and Planets" a useful reference text. The excellent reproductions of high-altitude solar spectra (to λ2400 in the ultraviolet), of planetary and laboratory spectra and of photographs of Mars are also features of great value. Most important of all, this book should stimulate research; it summarizes the subject at a time when great advances have become possible. A variety of research problems are pointed out specifically and many others are implied in the discussion.

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